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THESIS

IMPROVING AND INCREASING THE EFFICIENCY OF THE P-8A TEST WORK DESCRIPTION (TWD) PROCESS

by

James W. McDermott, Jr.

September 2009

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13. ABSTRACT (maximum 200 words)

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Corel's iGrafx software was selected to model the process. The model varied TWD development time and test team resource level to analyze alternative TWD development process concepts. Alternatives examined excursions from a baseline condition that was limited by the existing team resource level (the lower bound) to an upper bound that assumed unconstrained resources. The upper bound conditions represented the earliest time the TWDs could be completed. Additional alternatives were analyzed until an "optimal" resource level was found that would support the test program.

It is recommended this type of modeling be applied to other test programs and systems engineering processes to improve their efficiency.

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IMPROVING AND INCREASING THE EFFICIENCY OF THE P-8A TEST WORK DESCRIPTION (TWD) PROCESS

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This study's purpose was to identify opportunities to improve the P-8A test working description (TWD) process in support of the P-8A test program. This study researched other NAVAIR test programs that used a contractor and government integrated test approach. This study determined the proper balance of improvements to support the approval of TWDs to keep pace with the testing. The process was functionally decomposed to look for process redundancies, choke points and out-of-sequence sub-processes. Two changes were identified and implemented that reduced the process from five phases to four phases.

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EXECUTIVE SUMMARY

The purpose of this study was to identify opportunities to model and improve the P-8A test working description (TWD) process that would support the P-8A test program. This study researched other NAVAIR test programs that used a contractor and government integrated test approach. These test programs were the V-22, F/A-18E/F, and the E-2D. The three programs experienced similar challenges as they progressed through test execution. The P-8A program has already incorporated many of their lessons learned associated with defining roles and responsibilities. The research of these programs also found each program struggled with test plan throughput. Their solutions to this problem varied across programs and made it difficult to apply lessons learned in this area to the P-8A program.

The challenge for this study was to determine the proper balance of improvements to support the production and approval of TWDs to keep pace with the testing. This required further analysis of the P-8A TWD process. A software model of the process was built to analyze various scenarios to identify the balanced solution. To look for process redundancies, choke points, and out-of-sequence sub-processes, the study applied value stream mapping. After completing the initial functional decomposition, two additional changes were identified and implemented, which reduced the process from five phases to four phases. Following the functional decomposition, a computer model of the process was developed. Process changes based on the modeling have improved the quality of TWD written reports. As the additional staffing is applied, in addition to other changes suggested by the modeling, process time should also improve significantly.

This study used the software suite Corel's iGrafx Process for Six Sigma to model the process. By varying TWD development time, Integrated Test Team resource level, and by re-sequencing sub-processes, alternative TWD development process concepts were analyzed using the process model. Examined alternatives ranged from a baseline condition that was limited by the existing January 2009 Integrated Test Team resource level (the lower bound) to an upper bound that assumed unconstrained resources. The upper bound conditions were chosen to determine the earliest time the TWDs could be completed. The study also analyzed other alternatives whose conditions were in between those boundary conditions. Through this analysis, it was possible to identify an "optimal" resource level to support the test program, identified as Alternative B. Alternative B set the model's input parameters, so the TWDs were delivered at a rate that was just ahead of the flight test schedule need dates, thus providing an optimal solution. The selected alternative required the Integrated Test Team resource levels to increase by approximately 150 percent over the baseline, thus identifying a severe understaffing problem.

Application of this model to other NAVAIR test programs and systems engineering processes is underway and shows promise of improving their efficiency as well.

LIST OF ABBREVIATIONS/ACRONYMS/SYMBOLS

ACAT	Acquisition Category
AoA	Analysis of Alternatives
ASW	Anti-Submarine Warfare
ASuW	Anti-Surface Warfare
BAMS	Broad Aerial Maritime Surveillance
BPR	Business Process Reengineering
CDD	Capabilities Development Document
CDR	Critical Design Review
CFTD	Contractor Flight Test Director
COP	Common Operational Picture
CPD	Capabilities Production Document
CSG	Carrier Strike Groups
CT	Contractor Test
DAB	Defense Acquisition Board
DoD	Department of Defense
DT	Development Test
ERB	Executive Review Board
ESG	Expeditionary Strike Groups
FTE	Flight Test Engineer
GFTD	Government Flight Test Director
ISR	Intelligence Surveillance Reconnaissance
IOE	Instrument Operations Engineer
IOT&E	Integrated Operational Test and Evaluation
IPT	Integrated Product Team
ITT	Integrated Test Team
JROC	Joint Requirements Oversight Council
KPP	Key Performance Parameter
MCO	Major Combat Operations
MDA	Maritime Domain Awareness
MMA	Multi-Maritime Aircraft
MOA	Memorandum of Agreement
MPR	Maritime Patrol and Reconnaissance
NAWCAD	Naval Air Warfare Center, Aircraft Division
NAVAIR	Naval Air Systems Command
ORD	Operational Requirements Document
OT	Operational Test
PBSS	Performance Based System Specification
PE	Project Engineer
PO	Project Officer
SDD	Systems Development and Demonstration
SE	Systems Engineering

SLOC	Sea Lines-of-Communication
TC	Test Conductor
TE	Test Engineering
TPWG	Test Planning Working Group
TRA	Technical Readiness Assessment
TRB	Technical Review Board
TS	Training Systems
TWD	Test Working Description
UAS	Unmanned Aerial Systems
USAF	United States Air Force
USN	United States Navy

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I. INTRODUCTION

A. BACKGROUND

The P-8A (Poseidon) aircraft will be the next generation USN Maritime Patrol and Reconnaissance (MPR) system, specifically intended to replace the aging P-3C systems. The P-8A will have systems that provide capabilities to perform the current and future missions for the Maritime Patrol and Reconnaissance Force (MPRF).

An Analysis of Alternatives (AoA) for the MPRF was completed, and a final report was accepted 29 May 2002. The report identified manned aircraft as an essential element of the suite of systems that will satisfy the operational requirement (CJCS, 2003). The P-8A program underwent a 19-month Component Advance Development that resulted in the selection of the Boeing militarized 737 in September 2002. The Milestone B Defense Acquisition Board (DAB) review conducted 28 May 2004 approved the P-8A program's entry into the System Development and Demonstration (SDD) phase.

Since entering into the SDD phase, the P-8A program has completed several program milestones. It completed Preliminary Design Review in November 2006 and Critical Design Review (CDR) in June 2007. The two most recent program milestones were the Test Readiness Review (TRR) in May 2009, closely followed by the First Flight Readiness Review in August 2009. The first P-8A scheduled for flight test arrived at Naval Air Warfare Center, Aircraft Division (NAWCAD), Patuxent River, in late August 2009. Within the P-8A flight-test program, there are approximately 72 test plans, otherwise known at NAWCAD as test working descriptions (TWDs), for execution by the NAWCAD Patuxent River test team. These 72 TWDs need development, review, and approval. These test plans describe, in detail, how to exercise the system at appropriate points in the operating envelope of the system in an attempt to demonstrate the design's capability to meet threshold and objective technical parameters. Developing, reviewing, and approving these plans have not always followed a true standardized set of procedures.

B. PURPOSE

The TWD process is the Navy's process to develop detailed test plans for a flight test program. This severely challenged process is currently not well defined, and it does not provide the throughput necessary to meet the current P-8A test schedule. The purpose of this study was to model the current P-8A TWD process and identify opportunities to improve and increase the efficiency of the process. In addition to modeling the TWD process, this study documents all sub-processes, records interaction between the Boeing and USN test team, and identifies any shortages of critical skills.

C. RESEARCH QUESTIONS

This research addresses P-8A TWD Process requirements. The subsequent chapters address the following questions:

1. *Can modeling the P-8A TWD process allow opportunities to improve and increase the efficiency of the process?*
2. *Are there key resource elements and/or process steps that influence the efficiency of the process?*
3. *Can this simulation be applied to other systems engineering processes for the P-8A?*
4. *Is there applicability of this model to other DoD test programs?*

D. BENEFIT OF THE STUDY

There are several benefits resulting from this study, five of which are listed below. The first benefit is the baselining and documenting of the NAVAIR TWD process. The second benefit is improving the efficiency of the TWD process for the P-8A program so that it may meet the program milestones. The third benefit is a model that provides the proper sizing of the P-8A test-team staffing and necessary resources to achieve the required throughput of TWDs to meet the flight test schedule. The fourth benefit is the ability to apply the TWD modeling tool to other NAVAIR test programs.

The last benefit is identifying other P-8A systems engineering processes that this tool can simulate with minor model adjustments. Processes that could be possible candidates are the risk management process and engineering change process. These processes have similar steps compared to the TWD process. The TWD model can be adjusted with minor changes to account for their specific parameters. Results from the modeling can begin to identify opportunities to improve process efficiency and reduce the existing backlog of products.

E. SCOPE AND METHODOLOGY

This thesis focuses on baselining the current P-8A TWD process, modeling the process, and running simulations while varying key parameters to identify opportunities to improve the processes throughput. Key parameters within the model are test team skill-sets, availability of those skill-sets, available funding resources, complexity of the TWD, duration of each phase of the TWD process, percentage of rejected TWDs requiring rework, and availability of approval authorities.

To provide the baseline of the process, the study used information provided by test engineers, the Government Flight-test Director (GFTD), the P-8A Assistant Program Manager for Test & Evaluation, Boeing test engineers, the Boeing Chief Engineer, and the Boeing Flight-test Director. Research was conducted on other integrated test programs whose approach was to integrate developmental testing and operational testing. The objective was to understand the challenges of integrating a test team with both Government and Contractor personnel. The baseline process was modeled and simulation runs were conducted to understand the influence of each of the parameters. The author documented and analyzed the results to look for improvement within the process. Adjusting the process input parameters, more simulation runs were conducted to understand the impacts. By comparing the results back to the schedule constraints, the study aimed to determine the success of the improvement choices. The author created recommendations and submitted them to PMA290 for incorporation into the P-8A test program. In addition, the study conducted a review of existing systems engineering processes used within PMA290 that could benefit from this model. It provided recommendations to PMA290 leadership for possible incorporation to program operations. Finally, the author forwarded lessons learned from the model development and the implementation to AIR 5.0, NAVAIR's test community for possible application to other test program.

F. CHAPTER SUMMARY

This study begins with a review of the existing P-8A Integrated Test Team structure and goals. The review also includes researching the existing P-8A TWD process to understand roles, responsibilities, work environment, and constraints between the contractor and government. Chapter II provides an overview of the P-8A program. It describes the integrated test team approach and discusses earlier efforts to improve the TWD process. Chapter III describes how the DoD instructions define an integrated test program and the approach used by other USN integrated test programs to address their test planning hurdles. Chapter IV describes the selection of modeling software, construction of the model, including assumptions and inputs to develop the TWD model and its validation. Chapter V presents results from the simulations. Chapter V also presents recommendations regarding improved TWD process, the appropriate resource requirements, and applicability of this method to other NAVAIR test programs. Chapter VI provides the conclusions, and identifies possible systems engineering processes in PMA290 that could benefit from applying the modeling technique and other applications within the NAVAIR test community.

II. P-8A (POSEIDON) PROGRAM OVERVIEW AND TEST WORKING DESCRIPTION (TWD) PROCESS

A. INTRODUCTION

This chapter introduces the P-8A program organization, the Integrated Test Team (ITT), and the test working description (TWD) process. A TWD in simple terms is a detailed test plan that describes the test procedures and test points to achieve a desired test condition. Test data collected under a set of conditions that is used to verify performance parameters is a test point. The TWD process requires a significant amount of time and effort to position the P-8A program to execute the required test program successfully. A successful TWD process is one that delivers approved TWDs early enough to avoid delays in the actual flight test program.

B. PROGRAM OVERVIEW

The P-8A will replace the manned P-3C maritime patrol aircraft that currently provides broad area Anti-submarine Warfare (ASW) and Anti-surface Warfare (ASUW) capability along with substantial armed maritime Intelligence, Surveillance, and Reconnaissance (ISR). The P-8A Poseidon is principally an ASW platform that also performs ISR missions as a portion of an ISR Family of Systems, including the EP-3/EP-X signals intelligence platforms and the Broad Area Maritime Surveillance (BAMS) Unmanned Aircraft System (UAS). Figure 1 provides an illustration of a P-8A, which is a modified 737-800 aircraft, side by side with the P-3C.

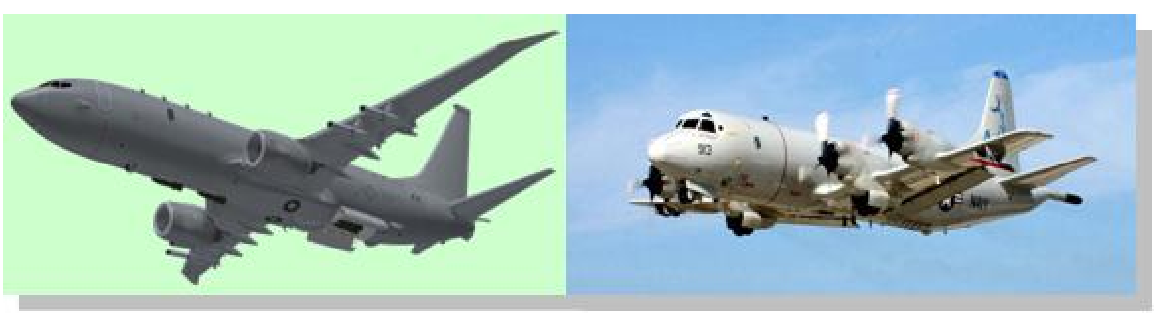

Figure 1. Pictorial depiction of P-8A and P-3C

The P-8A is a land-based aircraft that will conduct broad-area maritime and littoral patrol and ISR to provide Maritime Domain Awareness (MDA). It will contribute to the Common Operational Picture (COP) during peacetime and during buildup of tensions prior to commencing hostile operations. The P-8A will provide responsive, worldwide forward presence, engage allies and joint forces in exercises, contribute to maritime homeland security, and contribute to lesser contingency operations (e.g., disaster relief or non-combatant evacuation). During Major Combat Operations (MCO), P-8A will provide assured access for Carrier Strike Groups (CSG) and Expeditionary Strike Groups (ESG) to establish and maintain sea bases secure from hostile surface and submarine threats. It will also patrol and protect sea lines-of-communication (SLOC) against the same threats while contributing to the COP (CJCS, 2003).

The structure of the P-8A program organization has five major teams complementing program management: engineering, integration, testing, logistics, and training. The five teams are shown in the gray box located in the center of Figure 2, which shows the entire P-8A team organization. They make up the P-8A leadership teams along with Program Management. The five teams are broken down into sub-teams that address the major sub-systems, such as the air vehicle, mission systems, software, product support, manufacturing, testing, verification, training, and fleet introductions.

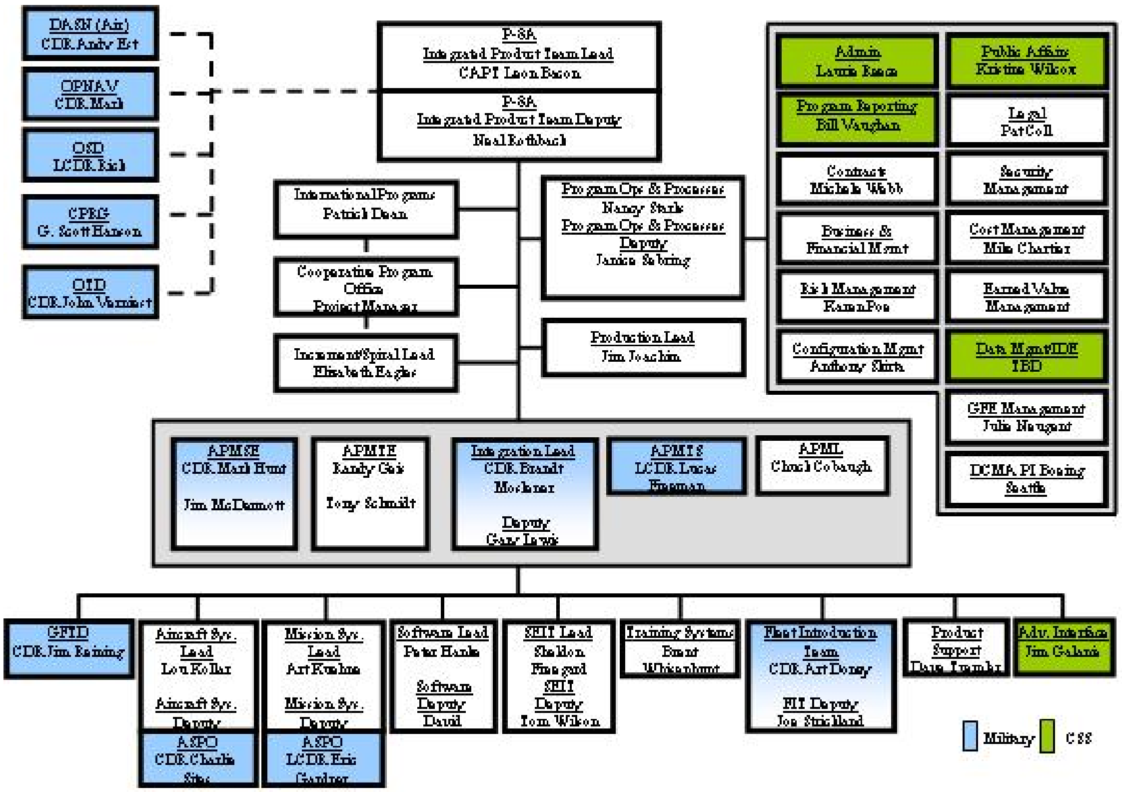

Figure 2. P-8A Integrated Product Team Organizational Chart

C. INTEGRATED TEST TEAM CONCEPT

Historically, there has been a difference between contractor and government testing. Contractor developmental testing focused on developing the aircraft's flight envelope. Government developmental testing concentrated on assessment of specification compliance as well as operational suitability. The government testing would assess the system's ability to meet key performance parameters (KPP) defined by the ORD. The KPPs have a threshold and objective values. A threshold is the minimum level of performance, and an objective is a desired level of performance. An example for a range KPP would be 800 nautical miles as a threshold and 1200 nautical miles as the objective. The distinction between a contractor DT and government DT is the contractor would strive to test to the threshold requirements. The government DT program would strive to find the actual capability of the product. As the Integrated Product Team (IPT) concept matured, NAVAIR recognized that there could be efficiencies captured within the test arena by combining contractor and government developmental testing.

Early in the SDD phase, the P-8A program decided to pursue an Integrated Test Team (ITT) approach to execute the verification phase of the program. This decision was based on recent successes of other large aviation acquisition programs such as Advanced Hawkeye (E-2D), Growler (EA-18G), and Super Hornet (F/A-18E/F). Each of these programs demonstrated that an integrated government/contractor teaming arrangement for Test and Evaluation (T&E) provided economies in cost and schedule as well as enhanced overall performance of the T&E effort. Leveraging this philosophy and applying lessons learned, the P-8A T&E approach is also using an Integrated Test Team, whereby both the prime contractor and the government share the test team activities. The P-8A program established a single team with representatives from the contractor and the government developmental and operational test communities. The task for this integrated team is to conduct the daily, on-site test and evaluation activities. The ITT prepares integrated test plans, executes the integrated test program, collects data, and maintains a common database. Utilizing the ITT concept maximizes the efficient use of time, resources, and work force during all phases of the P-8A test program except Initial Operational Test and Evaluation (IOT&E). Objectives of using the ITT concept are cited from the P-8A Test and Evaluation Master Plan (Office of Secretary of Defense, 2005):

- "Provide opportunities for Developmental and Operational Test evaluation of the P-8A system early in the development program."
- "Enable testing to address technical and operational test concerns at the earliest opportunity."
- "Avoid duplication of government and contractor testing and test data requirements. Combined testing provides an opportunity for government testing to "piggyback" on contractor development test and thereby avoids extra flight hours to collect data on measures that are only of interest to the government."
- "Provide an environment for coordination of testing within which ITT members can effectively and efficiently obtain data to execute their combined DT/OT mission."

A crucial factor that enables an effective and efficient ITT is the ability to conduct day-to-day business in the most autonomous manner possible. Authority is delegated to appropriate government and contractor personnel within the ITT to the maximum extent possible. Operating in this manner requires ground rules and clearly defined roles and responsibilities be assigned. NAVAIR and Boeing jointly developed a Memorandum of Agreement (MOA) that clearly identified roles and responsibilities within the test program. This was a lesson learned from the F/A-18 E/F program, which in their report back to Naval Air Systems Command leadership stated, “The complex nature of the ITT requires clear guidance of roles, responsibilities, and conflict resolution in order for it to be successful.” The MOA clarified issues such as governing documents, test scheduling, test air space, test facilities, organizational management, deficiency reporting, and access to Boeing and NAWCAD Patuxent River facilities. The MOA is a living document and is periodically reviewed and updated to reflect current programmatic and test environment.

There are three main components of the Integrated Test Team. These are Contractor Test, USN Developmental Test, and Operational Test. During the SDD phase, components have objectives described below and illustrated in Figure 3:

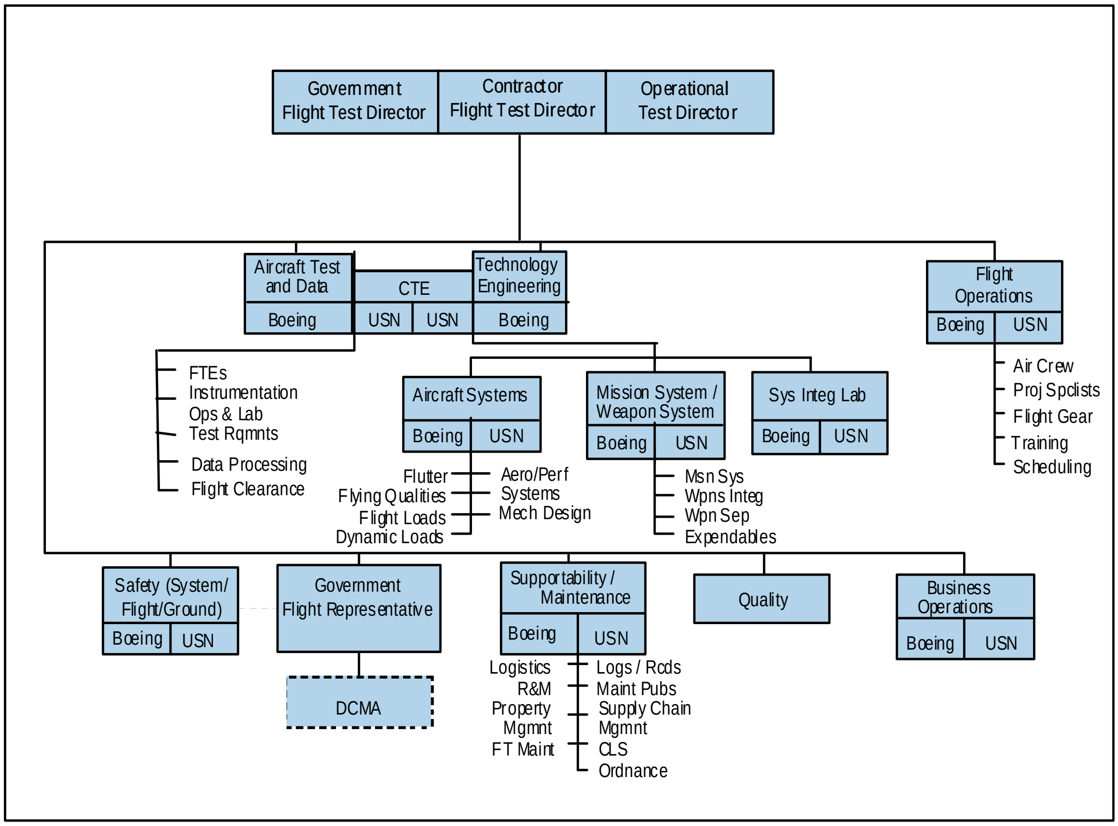

Figure 3. P-8A Integrated Test Team

- Contractor Test (CT) objective: Ground and flight-test SDD program to develop the P-8A Poseidon weapon system capability and to verify by test and demonstration that the aircraft and its systems meet contractual requirements as stated in the Performance Based System Specification (PBSS).
- Developmental Test (DT) objective: USN testing in conjunction with contractor testing to evaluate and verify capabilities required by the PBSS, as well as evaluation of the weapon system capability from a mission relation perspective.

- Operational Test (OT) objective: This is USN testing done in conjunction with contractor and USN developmental testing to evaluate mission suitability and mission effectiveness of the P-8A Poseidon weapon system as developed and evaluated during the ground and flight-test program.

Testing is conducted at two primary sites. The majority of the ground testing is conducted at Boeing facilities in Seattle, Washington. This testing includes static and fatigue testing. The primary site for the flight-test program is the U.S. Naval Air Warfare Center, Aircraft Division (NAWCAD), Patuxent River, Maryland.

D. P-8A TEST WORKING DESCRIPTION (TWD) PROCESS

A test working description (TWD) is a detailed test plan NAVAIR uses when conducting a test. There is a lengthy formal review and approval process familiar to the NAVAIR test community. There are 72 TWDs required to conduct the P-8A verification phase. After these TWDs are developed, they must undergo the review and approval process. A TWD's complexity can vary depending on the content of the testing. The level of review and approval is set by the level of complexity. Therefore, the complexity heavily influences the time it takes to get the TWD through the process. Figure 4 illustrates the original TWD approval process that the government test team intended to use. It also identifies the number of reviewers and approvers. The issue that was recognized but not thoroughly understood by both Boeing and NAVAIR, was the complexity of adding Boeing's contribution to that process. Early attempts to map out the process and time associated with this process were completed at a high level. Unfortunately, these attempts lacked details to understand the true impact on throughput. Figure 5 provides the simplistic view of the TWD process and its notional timeline. The NAVAIR reviewers, who would normally generate comments and recommendations, originally scoped the process to have an initial draft of the TWD followed by a review. The TWD moves through the process undergoing reviews and updates to mature the

TWD for submission for approval. The final review is the Executive Review Board (ERB). The ERB would either approve the TWD or assign actions to be completed prior to the TWD returning to the ERB.

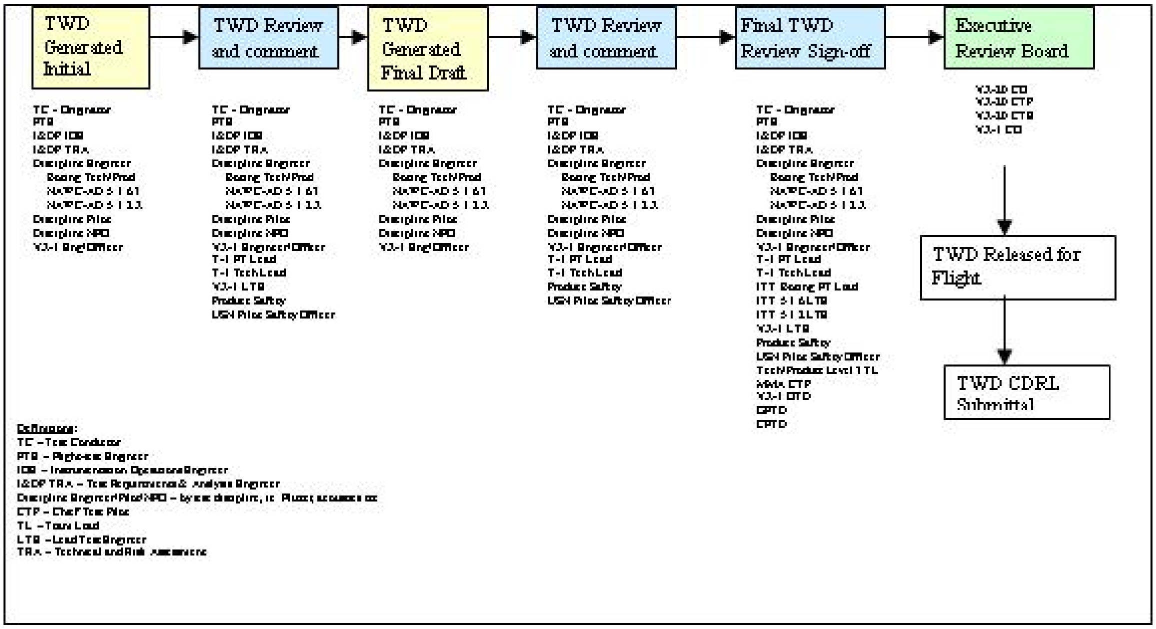

Figure 4. TWD Approval Process and Potential Reviews

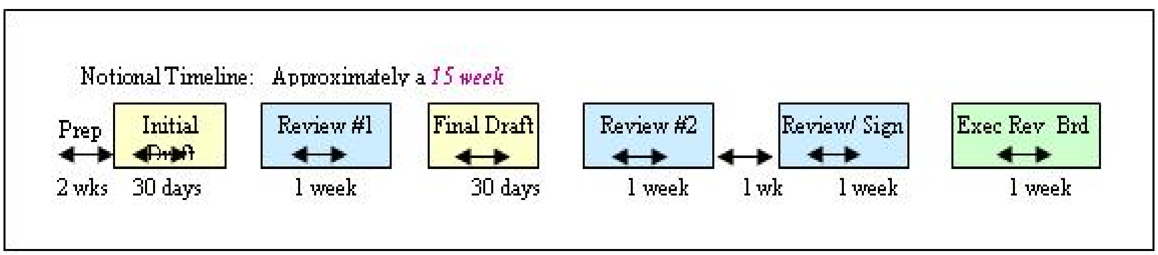

Figure 5. Early TWD Process Notional Timeline

This notional timeline gave a false sense of security that there was sufficient understanding of process duration. This proved to be in error as the team initiated TWDs for ground tests. By the time the P-8A program started to understand the ramifications of underestimating the TWD process, the Boeing technical team was downsized in line with the program's plan to maintain the program's expenditure profile. Boeing's 787 and 747 programs quickly absorbed the personnel slated to be part of the downsizing. This presented a significant challenge to the P-8A program because, appropriately, staffing the TWD process was becoming extremely difficult and the TWD backlog began to grow.

After several reviews, it became evident that a key element of maintaining critical program milestones was to perform an assessment of the TWD process, seeking opportunities to identify possible bottlenecks in the process and determine the appropriate staffing and resources required to efficiently develop, review, and approve the 72 TWDs. In November 2008, the P-8A program office and the ITT requested an in-depth review of the TWD process to include documenting a detailed process flow.

Figure 6 presents the detailed process flow that added granularity to the process and necessary insight to assess possible choke points. This process included several decision points a TWD must pass through prior to achieving ERB approval. Underneath each of the process blocks is the work and coordination that takes place to position the TWD to pass each checkpoint successfully. Unaccounted in this detailed flow under the original view, shown in Figure 5, was an increase in process time. The added detail began to pinpoint choke points within the process as well as highlight staffing deficiencies. The detailed process also identified that all TWDs are not the same and groups them into three different categories (A, B, or C). Each category has different approval paths. Category A has the lowest complexity level with approval authority at a lower level than category B or C. Category C is the highest complexity level, takes the longest processing time, and requires approval of senior Navy test leadership. Category B falls in between A and C with respect to complexity, duration, and approval authority. Even with the additional level of detail, this view of the TWD process still handicapped the P-8A program from fully understanding the risk the program was exposed to in the test program. To help fully understand the risk, it was decided to create a computer model to better characterize the TWD process for optimization opportunities.

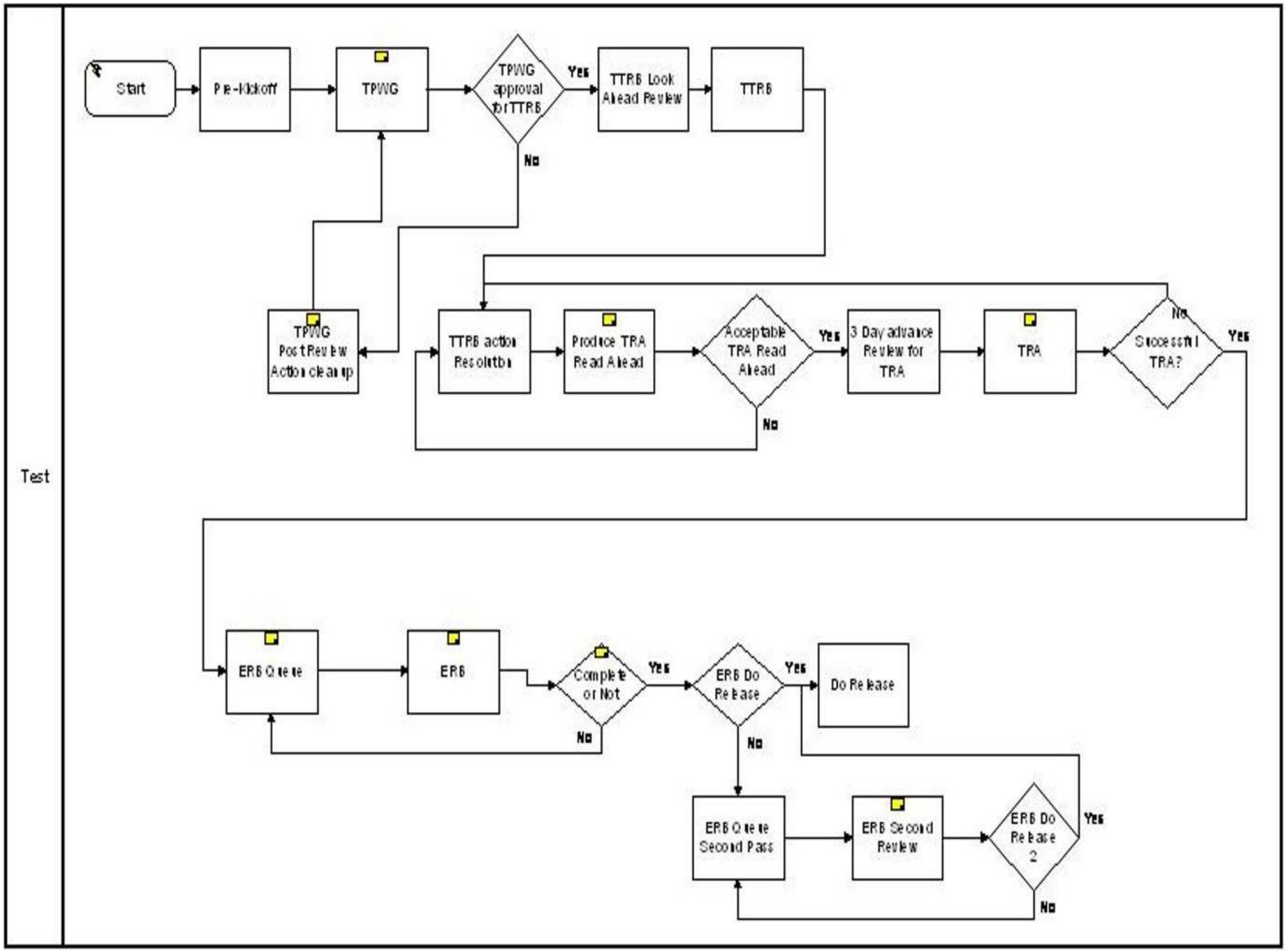

Figure 6. Detail TWD Process Flow

E. TWD MANAGEMENT TOOLS

Many tools have been used to improve the efficiency of business processes. Some of these are applicable to the TWD process. Two specific tools, Excel spreadsheets and Business Process Reengineering (BPR), were used earlier in the P-8A program with the goal to improve the efficiency of the TWD process. This section presents a discussion of these tools.

1. Early TWD Management Methods using Excel Spreadsheets

Early methods of managing TWDs through the TWD process ranged from the use of pencil and paper to using Excel spreadsheets. Tables 1 and 2 show samples of P-8A spreadsheets used within the ITT. As shown in Table 1, the spreadsheet tracks the name of the TWD as well as the test team associated with the TWD. The sheet lists the key personnel who develop and usher the TWD through its process. Table 2 tracks the progress of each TWD against the baseline date. The color codes for the tracker sheet are 'green' if the TWD is on schedule. The yellow shows the TWD is off schedule but meets need date and red means the TWD is off schedule and exceeds need date.

Table 1. The P-8A TWD Personnel Resource Excel Spreadsheet

TWD Title	Test Conductor	Project Engineer	Project Officer	Operational Test Representative	Fight Test Engineer	Technical Lead	Contractor Flight Test Director	Government Flight Test Director
AIRCRAFT WEIGHT & BALANCE	B, TC, AS	DT, PE, AS, AEROMECH	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH	CFTD	GFTD
FUEL SYSTEM GROUND TEST	B, TC, AS	DT, PE, AS, MECH SYS	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH	CFTD	GFTD
ECS GROUND TEST	B, TC, AS	DT, PE, AS, MECH SYS	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH	CFTD	GFTD
ELECTRICAL SYSTEM GROUND TEST	B, TC, AS	DT, PE, AS, MECH SYS	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH	CFTD	GFTD
EMC SOFT	B, TC, MS	DT, PE, MS, EEE	DT, NFO, PO, MS	OT, NFO, PO, MS	FTE	MS, TECH	CFTD	GFTD
HUMAN FACTORS	B, TC, HF	DT, PE, AS, HUMAN FACTORS	DT, NFO, PO, MS	OT, NFO, PO, MS	FTE	MS, TECH	CFTD	GFTD
AIRCREW GROUND EGRESS DEMO	B, TC, AS	DT, PE, AS, MECH SYS	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH	CFTD	GFTD
EXTERNAL FIELD OF VIEW GROUND	B, TC, AS	DT, PE, AS, GENERIC	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH	CFTD	GFTD
FQ FLIGHT TEST - CLEAN	B, TC, AS	DT, PE, AS, FQ	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH	CFTD	GFTD
STRUCTURAL LOADS GROUND & FLIGHT TEST -	B, TC, AS	DT, PE, AS, LOADS	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH	CFTD	GFTD
FLUTTER FLIGHT TEST - CLEAN	B, TC, AS	DT, PE, AS, FLUTTER	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH	CFTD	GFTD
TAXI/PRELIMINARY FLIGHT EVAL	B, TC, AS	DT, PE, AS, FQ	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH	CFTD	GFTD
HEALTH MANAGEMENT SYSTEM - FLIGHT TEST	B, TC, R&M	DT, PE, AS, MECH SYS	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH	CFTD	GFTD
PERFORMANCE FLIGHT TEST - CLEAN	B, TC, AS	DT, PE, AS, PERF	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH	CFTD	GFTD

Table 2. The P-8A TWD Tracking Spreadsheet

TWD TITLE / DESCRIPTION	Aircraft	TWD NO.	Schedule	TWD KICKOFF	1st DRAFT	Test Team Review (TTR)	Technical & Risk Assessment (TRA)	APPROVAL (ERB)	Test Conductor
Umbrella Test Plan (per NAVAIRINST 3960.4B)	T1, T2, T3	Umbrella	Plan	9/16/08	11/6/08	11/15/08	11/15/08	12/1/08	Dean Armstrong
			Forecast	9/16/08	11/6/08	1/8/09	1/8/09	8/10/09	
			Actual	9/16/08	11/6/08	1/8/09	1/8/09		
Fuel System Ground Test	T1, T2, T3	FBA05.01-001	Plan	4/1/08	4/14/08	6/1/09	6/22/09	7/7/09	Dean Armstrong
			Forecast	4/1/08	4/14/08	6/1/09	6/22/09	7/7/09	
			Actual	4/1/08	4/14/08				
Aircraft Weight & Balance	T1, T2, T3	FBA14.07-001	Plan	4/1/08	9/30/08	11/19/08	11/19/08	12/19/08	Dean Armstrong
			Forecast	4/1/08	9/30/08	2/19/09	2/19/09	3/6/09	
			Actual	4/1/08	9/30/08	2/19/09	2/19/09	3/31/09	
Electrical System Ground Test	T1, T2, T3	FBA05.04-001	Plan	4/15/08	4/28/08	8/29/08	8/29/08	9/29/08	Dean Armstrong
			Forecast	4/15/08	4/28/08	2/13/09	2/13/09	3/10/09	
			Actual	4/15/08	4/28/08	2/18/09	2/18/09	3/10/09	
EMC SOFT	T1	FBA04.12-001	Plan	1/5/09	5/8/09	5/22/09	6/5/09	6/19/09	Don Arbuthknot
			Forecast	2/23/09	5/8/09	5/22/09	6/5/09	6/19/09	
			Actual	2/27/09					
Aircrew Ground Egress Demonstration	T1	FBA14.01-004	Plan	3/2/09	4/10/09	5/26/09	6/9/09	6/23/09	Nick Shields
			Forecast	3/20/09	4/10/09	5/26/09	6/9/09	6/23/09	
			Actual	4/2/09	4/10/09				
Human Factors Demonstration	T2, T3	FBA14.01-002	Plan	2/16/09	3/27/09	5/26/09	6/9/09	6/23/09	Nick Shields
			Forecast	3/13/09	5/1/09	5/26/09	6/9/09	6/23/09	
			Actual	4/16/09	5/1/09				

Completed
On plan/target for performance period
Marginally off plan/target for performance period (<14 Days)
Significantly off plan / target for performance period (> 14 Days)

2. Business Process Reengineering (BPR) Application

Deadlines for TWDs were quickly approaching and progress was minimal. The flight test schedule was in jeopardy. It became apparent that an overhaul of the process was necessary and that the business process reengineering (BPR) approach could apply. A study from Hammer and Champy (1993, cited in Nahmias, 2005) defines BPR as a process of challenging the way business is currently conducted. It does not accept the answer, "because that's the way we do it." Applying BPR is not very difficult but does have five general principles to follow. The five principles are listed below, with notes on how they were applied within the P-8A process:

1. Several jobs are combined into one: Merging the contractor's process with Navy DT/OT test plan process provided an opportunity to streamline and integrate each process. The contractor's ability to execute the test program can be combined with the Navy's ability to conduct test programs with ordnance while maintaining a strong safety emphasis.
2. Workers make decisions: The engineers, test conductors, project officers, and technicians establish the TWD content, data requirements, success criteria,

and test sequences. The engineers define what data must clear a test sequence while the test conductors and technicians define the efficient approach of obtaining the data.

3. The steps in the process are performed in a natural order: There were initial struggles in this area as the contractor and Navy began to combine their processes into a single approach. The approval of a single TWD was different between the two entities. The Navy had a much more rigorous safety assessment than the contractor. The newly integrated process addressed results of hazard analysis at each major process review.
4. Process should have multiple versions: The development and approval of a TWD employed two basic approaches.
    a. A single writer of the TWD owns its contents and its success criteria and is responsible for its final approval. The writer consults with other key technical members as needed.

    b. A team is assembled to oversee the TWD’s creation and approval. The team is comprised of engineering and test disciplines that directly influence the TWD. A test conductor is assigned as the leader of the team. His primary responsibility is ensuring identification of all key players, scheduling of the approval board, and resolving team conflicts. This approach proved to be effective in dealing with complex TWDs.
5. Perform work where it makes sense: This principle turned out to be difficult with one part of the test team working from the West coast and the other on the East coast. They established core hours to minimize inconveniences. Leveraging web conferencing allowed the TWDs to be worked simultaneously with both coasts.

Employing the BPR technique generated areas of opportunity to improve the process at the macro level. The BPR identified duplication of effort during the reviewing cycles of the TWD. The P-8A test team leaders changed the reviews from a serial flow to a parallel flow. The assigned team conducted Web-based conferencing review enabling real-time editing of the TWD. These changes provided significant reduction in process time by obtaining all team members' participation and team ownership of the TWD early in the process. This technique also allowed both the Navy and the contractor to insert their unique attributes, test safety, and test efficiency, in the TWD up front. Despite the improvements brought about by employing BPR, the P-8A program still lacked the capability to predict TWD production rates as a function of resource levels. The shortcoming in the TWD production rate prediction is what led to the author's modeling efforts described in Chapter IV.

F. CHAPTER SUMMARY

This chapter provided an overview of the P-8A program. The P-8A is the replacement of P-3C aircraft having the anti-submarine warfare (ASW) as its primary mission. The chapter provided the organizational structure of the P-8A program. It described the ITT concept being employed to conduct the verification phase of the program. The P-8A program adopted lessons learned from other large NAVAIR ACAT-1D programs such as F-18E/F and E-2D. The chapter described the three ITT objectives, illustrated the ITT organization, and defined the different components of the ITT.

Finally, this chapter provided the description of the TWD process as it was originally defined. It described the shortfalls and challenges of using the original simplistic process flow. The chapter summarized the program office's and the ITT's earlier attempts to revise the TWD process, which enhanced its detail. This added detail highlighted possible opportunities to improve the process but also revealed the risk created by not having a full understanding of the process characteristics. At that time, the author initiated the TWD process modeling.

III. RESEARCH ANALYSIS

A. INTRODUCTION

This chapter presents the Department of Defense Directive (DoD) 5000.01 view of integrated testing. It describes the planning requirements, the role of the prime contractor, and responsibilities of developmental and operational testing personnel. This chapter also discusses lessons learned from F/A-18E/F, E-2D, and V-22 acquisition programs, which employed an integrated testing approach. The challenges and successes these programs experienced helped shape the P-8A integrated test program. This section also discusses how each of these teams established their team structure and how their procedures benefited their programs. The focus of this chapter extends beyond the TWD processes of earlier programs; however, the extension is needed because understanding test execution is essential for developing realistic and effective TWDs.

B. DEPARTMENT OF DEFENSE POSITION ON INTEGRATED TEST

DoD Directive 5000.01 states that integrated test and evaluation needs to be conducted throughout the acquisition process. The purpose of test and evaluation is to assess the technical maturity, interoperability, and operationally effectiveness, and confirm compliance to technical performance requirements. The DoD Instruction 5000.02 states:

> Developmental and operational test activities shall be integrated and seamless throughout the phase. Evaluations shall take into account all available and relevant data and information from contractor and government sources.

An Office of the Secretary of Defense Memorandum issued in 2007 states:

> To maximize the efficiency of the T&E process and more effectively integrate developmental and operational T&E, evaluations shall take into account all available and relevant data and information from contractor and government sources.

This policy, along with that in DoD Directive 5000.01, empowers the T&E community to achieve the goal of early identification of technical, operational and system deficiencies so that corrective actions can be incorporated in a timely fashion.

C. REVIEW OF OTHER PROGRAMS THAT USED INTEGRATED TEST TEAM APPROACH

Employing an integrated test approach is not a new technique within the DoD and especially within the USN. The United States Air Force (USAF) pioneered integrating contractor and government testing and modeled it after the Integrated Product Team (IPT) found throughout government and industry. VanderVliet and Price (1996) identify the USAF as successfully employing combined test team approach in 1972 on the F-16 program, the first Acquisition Category 1 (ACAT 1) program. The USN slowly began to adopt this new philosophy within its T&E community. Several aircraft test programs successfully integrated developmental and operational testing. An integrated test team comprised of government developmental and operational testers and prime contractor testers was employed to conduct testing. Their success did not come without overcoming several hurdles that developed into lessons learned for other programs' application. From these lessons learned, the P-8A Integrated Test Team established their operating procedures, roles and responsibilities, and team structure on expectation of achieving similar efficiencies.

1. V-22 Integrated Test Team Lessons Learned

The USN embarked on the road to integrated test in February of 1993 with the V-22 Osprey program. The goal was to reduce redundant flight-testing between contractor testing and government testing that was the normal mode of verification testing at this time. This would allow for early detection of design deficiencies and corrective actions without adversely impacting the program schedule and cost. Early in the test effort, the V-22 program discovered contractual roadblocks that limited government pilots and engineers to acting only as monitors. The limited scope of government test participation prevented the achievement of government developmental test objectives. This resulted in significant lost opportunity of efficiency. Because of the limited participation, the government had to conduct its own separate developmental flight-test.

Figure 7. V-22 Test Asset at NAWCAD Pax River

The program continued to face challenges as it entered into new territory within the USN test community. One specific area of contention was that the combined testing with the contractor threatened the government test team’s independence and authority. Ultimately, the defining of the roles and responsibilities in a Memorandum of Agreement (MOA) initiated the team-building process. In addition, team members recognized they would need daily operational procedures that included jointly planned flight operations if they were to function effectively as a team. These procedures became known as ITTOPS, Integrated Test Team Operating Procedures. The development of these procedures revealed to the team the scope of work in front of them. ITTOPS also helped foster buy-in by all members that proved valuable as the testing progressed. One other element that infused the drive to “succeed as an integrated test team” was that both test teams were accountable for the execution of the test program. This emphasized the importance of communication of new ways of conducting testing to infuse efficiencies into the test program.

Lessons learned for future programs drawn from the V-22 program were:

1. Ensure the contract is structured to allow for maximum participation of the government representatives to achieve optimal test efficiency.

2. Establish a MOA early in the program that clearly defines roles and responsibilities to foster the team building process.

3. Develop and implement ITTOPS that are mutually approved by the contractor and affected government entity.

These lessons learned were recognized and were leveraged into the P-8A test program.

2. F/A-18E/F Test Team Lessons Learned

The F/A-18E/F program recognized early that clear direction on the execution of the test program was necessary, since it was moving away from the traditional USN test philosophy. They realized that mutual agreement was required on several key documents to minimize confusion, conflict, and to allow for maximum efficiency of the test program. These documents were:

- The contract that governed the legal responsibilities
- The Test and Evaluation Master Plan (TEMP) the government document that defines the acceptable performance requirements for the test program
- The Master Test Plan that resides with the contractor and details the entire weapons system test program
- A Memorandum of Agreement (MOA) established between the contractor and government defining roles and responsibilities within the ITT (Springsteen, Bailey, Nash, & Woolsey, 1999).

Figure 8. F/A-18 Super Hornet at Pax River

The contract assigned the contractor with the responsibility of being the team lead within the ITT. This was a first for USN testing and, as with the V-22 test program, the government test team viewed this as making them subservient to contractor. The contract vehicle defused some of the caustic issues, but it did not eliminate all of them.

The program reinforced the position of an integrated test program by capturing the requirements within the F/A-18E/F TEMP and the Master Test Plan. The TEMP directs the structure and scope of the developmental and operational test program to include scheduling and resource allocation. It defines the Government Furnished Equipment (GFE), test venues, required work force, and necessary training. The contractor complement to the TEMP is the Master Test Plan. It is maintained by the contractor and provides details of the entire weapons system developmental test program from initial ground tests of models and test articles through the flight and system tests leading up to Operational Evaluation (OPEVAL).

The final key controlling document that was an enabler to the integrated test program was the F/A-18E/F MOA. The program leadership recognized the complexity of integrating the contractor and government test team and that team roles and responsibilities would require an agreement by all parties. The MOA clearly defined ground rules, test plan approval procedures, roles responsibilities, and authority. Quite often during the test program, the team members referred to it. The MOA also addressed a key discrepancy reporting process that had large implications to the contractor. This reporting process is discussed in more detail later in this section.

The program moved into new territory by combining test plans. This resulted in a valuable undertaking. In a traditional test program, the contractor would write a test plan and submit it to the USN. The USN would take the contractor test plan as a model to construct their own test plans that they would use for evaluation. It became clear that they needed a single combined test plan format as part of the integrated testing concept. To accomplish this, the contractor and USN ITT leadership created a test plan format that combined all of the elements of the contractor and USN test plans under one cover and with one sign-off and approval sheet. This turned out to be difficult at the start, but later resulted in a great team-building process.

One additional key factor that allowed the program to be successful was establishing a deficiency reporting process. The process had large implication to the contractor because disagreement on a deficiency causes the test program to stop until a resolution was reached. The contractor was responsible for execution of the test program. They are also responsible for the delayed schedule, and ultimately the increased cost of the program. The USN test team viewed this process as an opportunity to display their independence. To develop a process that all parties could operate under proved to be challenging but the team was successful in establishing one. The process was formal and meticulous and instituted discipline due to the high visibility the discrepancies received throughout the ITT and up through the higher echelons of NAVAIR and Boeing. Figure 9 displays the process that describes the start of an anomaly as a watch item and the disposition actions that it could take to be resolved. If immediate corrective actions are effective, the watch item can be resolved. If the watch item is not resolved, it converts to a white paper. Finally, if the issue is not able to be resolved, the white paper becomes a discrepancy requiring redesign and retesting. The ITT needed to "disposition" these issues quickly so mutual agreements on definitions, disposition board composition, and final authority were critical.

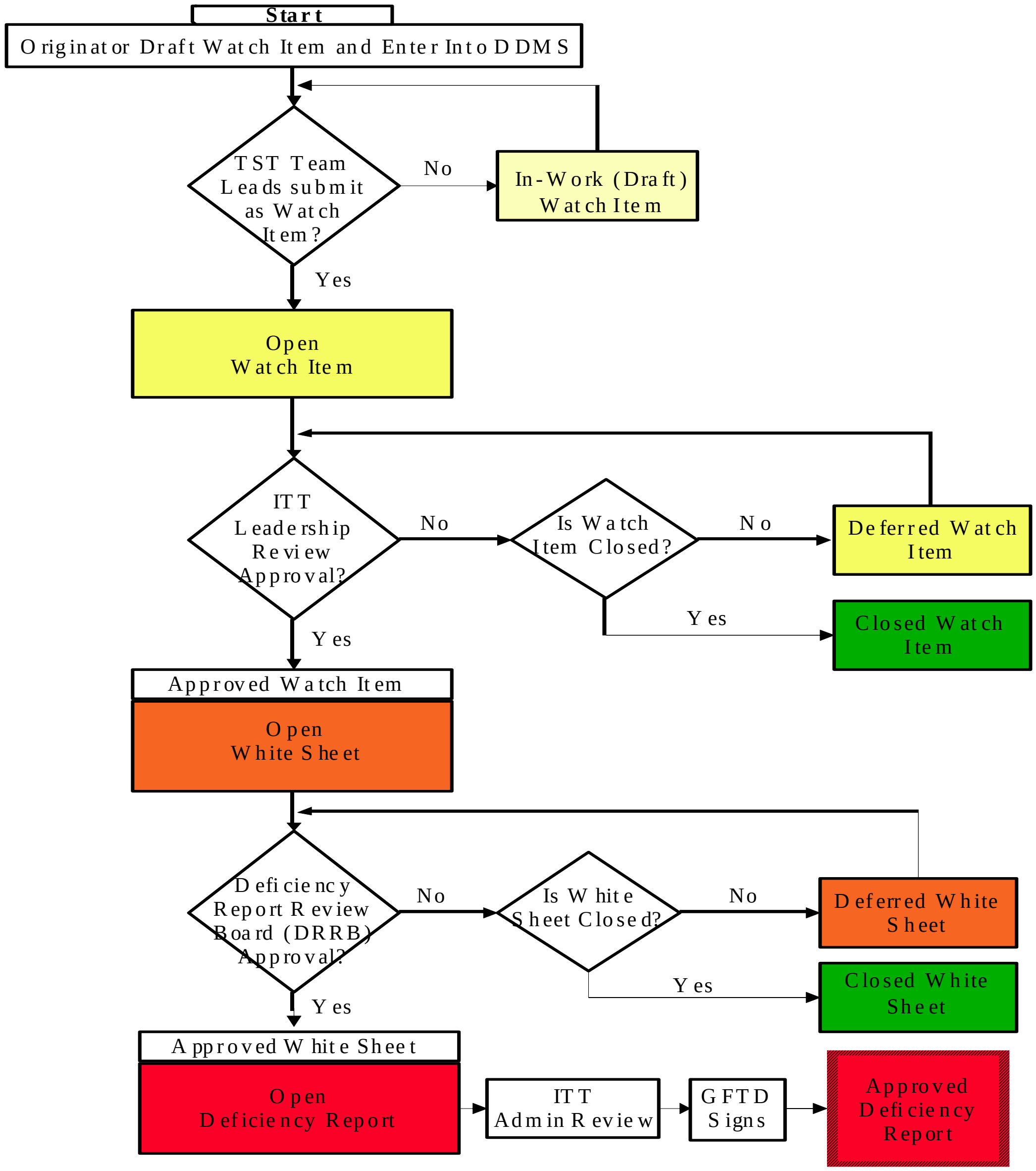

Figure 9. ITT Deficiency Management Process

Summarizing lessons learned from the F/A-18E/F, the following steps were recommended:

1. Establish controlling documentation early to achieve buy-in from both contractor and government testers as well as program management
2. Combine test plan development and approval to lean the process and leverage an opportunity for team building
3. Establish a discrepancy reporting process that with joint agreement of anomaly criteria

3. E-2D Integrated Test Team Lessons Learned

The most recent Navy aircraft program to enter into the integrated test arena is the E-2D. The program was built on lessons learned from the V-22 and F-18E/F but also generated methods of few of their own. The E-2D program established new benchmarks within the Naval test community by taking the integrated test to the next level by initiating the flight-test program in April 2007 at Northrop Grumman's facility, their East Coast Manufacturing Center in St. Augustine, Florida. Prior programs had conducted the flight-test at Naval Air Warfare Center, Aircraft Division, Patuxent River, Maryland, which required the contractor to position its test team at the government test facility. The E-2D program decided to conduct the initial phase of their flight-testing at the contractor facility. This required prepositioning a core government test team at the contractor's facility. This change resulted in new challenges facing the ITT regarding the roles of the organization. The contractor flight-test director (CFTD) was assigned the responsibility, authority, and accountability for the test program but the government flight-test director (GFTD) was delegated with the final authority over the daily flight schedule. This conflict of authority often influenced the schedule when not resolved quickly. NAVAIR gave CFTD the authority over the daily flight schedule, and this solved the problem.

Figure 10. E-2D Advance Hawkeye Test Asset

Another feature resulting from the government prepositioning their core team at the contractor facility was that the government team was completely comprised of volunteers. The additional insight that the E-2D ITT participants discovered was the core team members needed to be mission-oriented, open-minded, and cooperative to compensate for the reduced team size.

The working rules were also different for the contractor and government personnel. Each group had different holiday schedules, overtime rules, and award compensation practices. While not desirable, these differences were largely unavoidable under the strict government guidelines and work rules. Establishing a common set of work rules became necessary to maintain morale in this case where the government and contractor test teams worked in the same facilities.

Key lessons learned from the E-2D ITT included the following guidelines:

- Provide the necessary authority commensurate with the assigned accountability.
- Assemble the core team that is focused on positioning the test program for success.
- Create an equal working environment for all members of the team.

D. CHAPTER SUMMARY

This chapter examined the DoD perspective on integrated testing, beginning with the guidance in the formal acquisition instructions. It also researched a few of the larger USN aviation programs that have applied these instructions. While these programs discovered challenges, they were able to resolve those issues and to execute a successful integrated test program. Each program developed lessons learned for later programs to leverage into their own program. A common theme that each team conveyed is to identify roles and responsibilities that included accountability and authority early in the program. The ability for government and contractor to operate as an integrated team takes commitment and good communications. Combining processes to reduce the duration of the testing has tremendous advantages but requires both sides to yield on some their long held traditions. The P-8A program built their ITT from the lessons learned by the programs that preceded them and has successfully incorporated most of those lessons. The P-8A program also recognized that an optimized, combined TWD process was a key to successful testing and that there was an opportunity to pass on an effective lesson learned to following programs.

IV. TEST WORK DESCRIPTION MODELING

A. INTRODUCTION

This chapter examines the various software models assessed for use in building the TWD model. The chapter discusses the criteria applied in selecting the software and presents the chosen software. This chapter also looks at the construction of the TWD model. It presents the assumptions and inputs used in the model. Finally, this chapter discusses the different concepts analyzed by the model and presents early results from the model.

1. TWD Model Process

To determine opportunities to improve the efficiency of the TWD process, it was necessary to model the TWD process, as understood, in its unmodified state. To build the original model, the author began by interviewing several members of the ITT representing both government DT/OT and the contractor membership and revisiting the detailed process shown in Figure 6 and repeated in Figure 11. The members used the detailed process displayed in Figure 11 as the baseline functional description. It was interesting to note that while there was a consistent understanding among the members at the macro level, represented in the figure, the viewpoints began to diverge while mapping the process details.

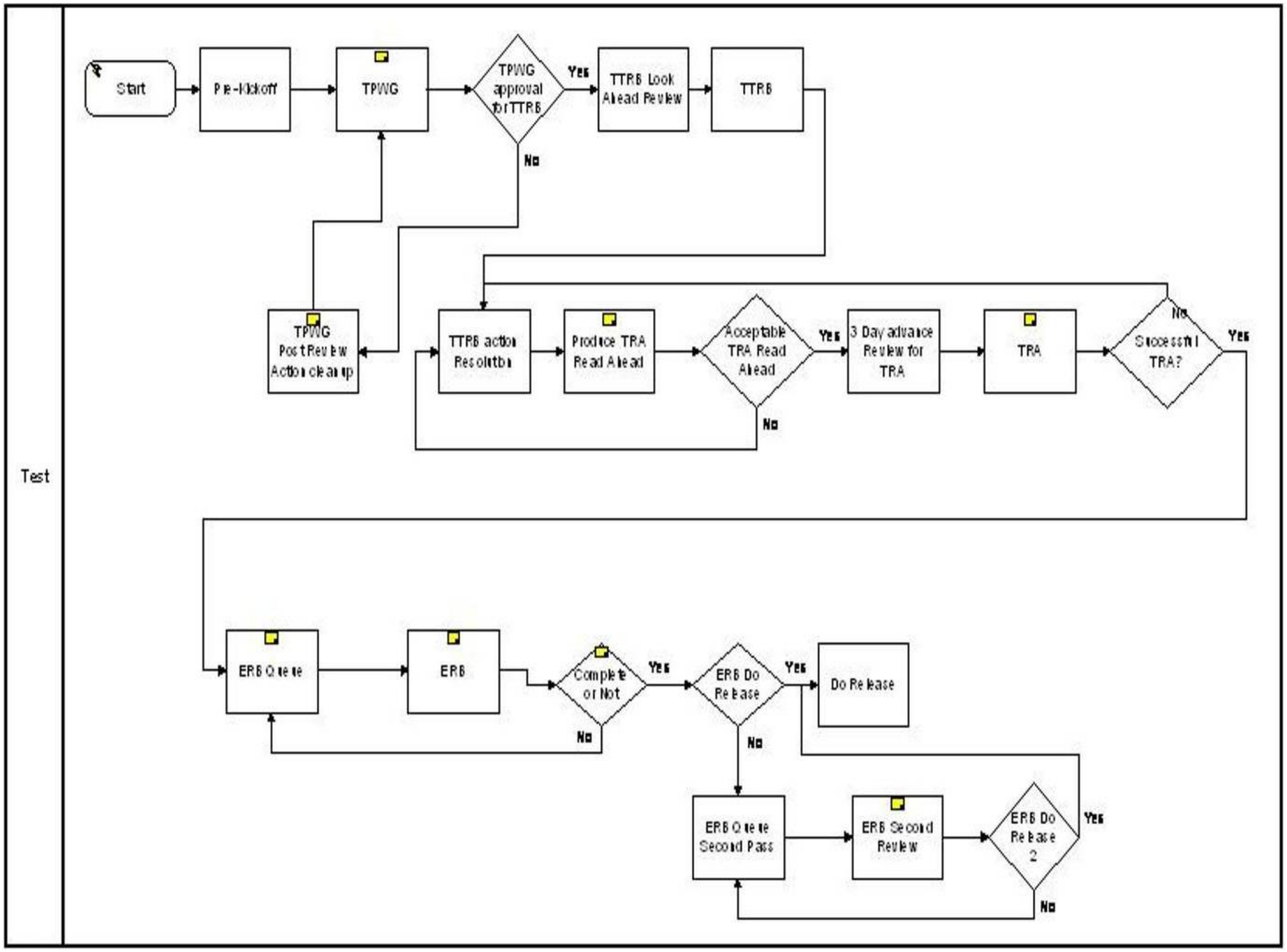

Figure 11. Baseline TWD Process

The re-examination of the TWD process uncovered two opportunities for improvement. These improvements resulted in the modification of the baseline process from a five-phase approach to an improved four-phase approach and streamlined the approval process for TWDs that were lower in complexity. The initial improvement modified the test plan working group sub-process to capture the first draft of the TWD and included developing an entry criteria checklist for each technical review. Under the modified process, the TWD entered the TPWG phase with mature engineering and test requirements, before moving to the next phase. The draft remained with the TPWG until the assigned test conductor determined its maturity for submission to the TTRB. In conjunction with this new four-phase approach, definitions of entry and exit criteria for the TTRB and ERB were established. This approach is consistent with the NAVAIR Systems Engineering Technical Review (SETR) process, which has been a valuable tool for program management. Figure 12 shows the improved TWD process. The four-phase approach consists of requirements review, first draft, TRA, and ERB. The final product from the ERB is an approved TWD.

The first phase of the improved process is the requirement phase of the TWD. In this phase, the test conductor is responsible for assembling the requirements and developing test content with the assigned test team. The product from this phase is an initial draft of the TWD. Duration of this phase can vary depending on the complexity of the TWD but the average time is approximately five months.

The initial draft enters the second phase where it undergoes a series of team reviews beginning with the TPWG and completing with TTRB. These reviews prepare the TWD to enter the formal independent technical reviews by review panels made up of senior members of the NAVAIR test community.

The third and fourth phases are the formal reviews. The third phase is the technical readiness assessment (TRA), which reviews the TWD for technical execution, safety, proper documentation, and aircraft configuration to among other areas.

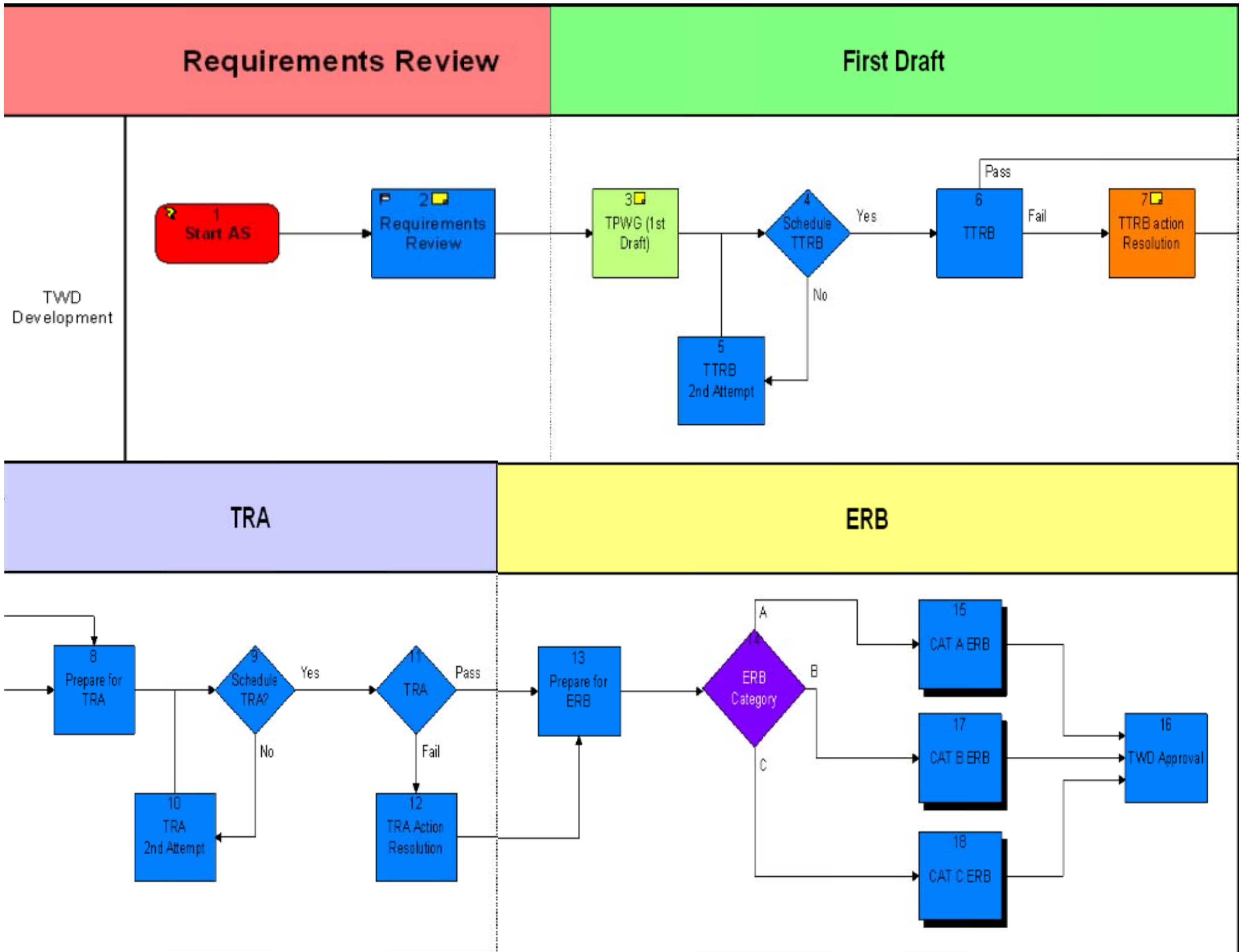

Figure 12. Improved TWD Process

The fourth and final phase is the Executive Review Board (ERB). The challenge with the ERB is availability of a single individual who has approval authority. Some of the areas on which the ERB concentrates are personnel certification, flight clearance, safety, test content, and aircraft configuration. The improved TWD process identified the ERB as a potential choke point for approving TWDs. To help improve the flow of TWDs, the Test community increased the number of approving officials from one to three.

The second improvement opportunity came as it became clear that not all TWDs are the same but rather fall into three categories. The three categories as defined by NAVAIR Instruction 3960.4B are category A, B and C, based on complexity and type of testing. Category A is the least complex and requires the minimum amount of time to process for approval. An example of category A is antenna pattern testing or laboratory testing. The most complex TWD type is category C. It requires a greater amount of time and resources than the other two categories. An example of category C is flutter testing. Correctly identifying the correct category streamlined the approval process for the category A TWDs by allowing a lower level authority to approve the TWD.

The above process changes did increase the quality of TWD write-ups. Time savings may also appear as the ITT becomes more familiar with the process changes.

2. Commercially Available Software Research

Based on review of the initial functional decomposition, the TWD process improvements were still not sufficient to complete the TWDs in time to support the flight test schedule. In addition, the ability to identify required resources, analyze different scenarios, project completion dates, and automate tracking for each TWD was still missing. The manual tracking of the TWDs was cumbersome, time consuming, and prone to errors. The program needed an automated system.

Initial efforts to develop a unique software suite to model the TWD process were abandoned because of the program's urgency to have an operating system before upcoming T-1 Test Readiness Review (TRR) scheduled for April 2009. The ITT commenced pursuit of more readily available commercial modeling software that would allow meeting the TWD process schedule requirement. Commercially available process modeling software is prevalent and most are capable of simulating all of the desired functions. The following are names of the software programs that were assessed: *Simcad Pro (Dynamic Simulation, 2009), Savvion Process Modeler (Savvion Process Modeler, 2009), Corel iGrafx (iGrafx Process for Six Sigma, 2009),* and *Rockwell Automation Arena (Value with Enterprise Wide Simulation-Corporate Perspective, 2009).* Each software suite had very similar capabilities. These capabilities include:

- conducting simulations
- generating tabular reports
- graphical output
- performing risk and statistical analysis
- conducting what-if drills
- creating process maps and lean value stream map diagrams
- analyzing schedule for improvement opportunities
- assessing resources requirements

These business processing modeling software packages support a broad range of applications throughout today's industries. Health, energy, clothing, trucking, and manufacturing industries all use the software. Businesses are continuously looking to reduce the cost of doing business and applying this software allows them to optimize their business processes *(Dynamic Simulation, 2009).* Most of the assessed software suites have Six Sigma tools that provide a capability to create value stream maps. Value stream mapping allows for the analysis of the flow of material and information leads to a final product. The software suites reviewed had similar capabilities as far as building process maps, generating reports, running simulations using normal and uniform distributions to create the demand on resources, and duration of required resources demand.

3. Modeling Software Selection

Based on initial stakeholder interviews, requirements were developed, constraints documented and the software suites' ability to meet those requirements was assessed. Among the key requirements were the ability to perform statistical analysis and generate graphical outputs such as value stream maps, compatibility with Microsoft products, relatively low cost, and availability. Table 3 lists those attributes and requirements.

Table 3. Requirements for Process Optimizing Software

Operating Software	Be compatible with Microsoft Windows
Software Tools	Be capable of Statistical Analysis, Cost & Schedule Analysis, Value Stream Mapping, Flow Chart, Risk Analysis, Process Optimization, Graphing
Graphical Output	Be compatible with Microsoft products
Tabular Output	Be compatible with Microsoft products
Cost	Cost below $1,500
Availability	Be available within 15 days
Simulation & Modeling	Have built-in capability, scalable,
Graphical User Interface (GUI)	Be Interactive, User Friendly
Import/Export Files	Produce Microsoft compatible files
Tutorials, Help	Must be Interactive, User Friendly
Hardware Requirements	Must be capable to be run on Desktop or Laptop with 160GB hard drive, 2 MB RAM, 1.8MHz

The four software suites were scored against the requirements. The author employed a simple design selection matrix to compare software candidates. Software meeting each requirement received a score of five (5); a partially met requirement received a score of three (3); and a software not meeting the requirement received a score of zero (0). The requirements were reviewed with the Government Flight Test Director (GFTD) and their priorities established. Based on their importance, requirements were weighted by the GFTD who is one of primary recipient of the of the model output. The author totaled scores for each software suite evaluated. Results from the scoring event revealed Corel iGrafx was marginally better than Rockwell's Arena. A major factor that gave iGrafx the edge over Arena was the cost and availability. The Naval Air Systems

Command employed iGrafx to support their process improvement initiatives. This allowed for immediate access to the software and eliminated the software cost to the program. Table 4 contains the results of the assessment.

Table 4. Scoring of Software Suites

		Name Software			
Modeling Software Attributes	**% Weighted**	Simcad Pro	Savvion Business Manager 7.0	Corel iGrafx 2007	Rockwell Automation Arena
Operating Software	10%	0.5	0.5	0.5	0.5
Software Tools	15%	0.75	0.75	0.75	0.75
Graphical Output	10%	0.5	0.5	0.5	0.5
Tabular Output	10%	0.5	0.5	0.5	0.5
Cost	15%	0	0	0.75	0.45
Availability	15%	0.25	0.25	0.25	0.25
Simulation & Modeling	15%	0.75	0.75	0.75	0.75
Graphical User Interface (GUI)	5%	0.25	0.25	0.25	0.25
Import/Export Files	5%	0.25	0.25	0.25	0.25
Total Score	**100%**	**3.75**	**3.75**	**4.5**	**4.2**
Scoring Criteria: 5 - Requirement Met; 3 - Requirement Partially Met; 0 - Requirement Not Met					

B. MODEL DEVELOPMENT

1. Model Objective

The objective of this model is to provide the capability to the ITT and the P-8A Program Office to explore the impact of resource levels or throughput of test plans (TWDs) on the cost and schedule of the flight test program. The ultimate objective is to make sure TWDs are produced in a cost efficient manner on a schedule that supports the flight test programs' needs.

In researching the different approaches to model the TWD process and resource requirements, there was a large amount of information on application of business process modeling. This was no surprise, since most businesses now focus on leaning out their processes to minimize the cost of doing business. An example of this application within NAVAIR is the AIRSpeed program. The sole purpose of AIRSpeed is to review processes within NAVAIR's charter and determine opportunities to be improved using Six Sigma, Theory of Constraints principles, and commercial industries lean initiatives. Consistent with the NAVAIR AIRSpeed, the same methodologies and toolsets were employed on the TWD process. Theory of Constraints was very applicable within the TWD process. The process has multiple constraints modeled to determine which constraints would yield the highest return on investment if optimally adjusted. In the below bullets, Harden (2004) provides some insight into NAVAIR's motivation to change the current culture to improve corporate processes.

- Enterprise AIRSpeed integrates best business practices, which includes Basic and Advanced Theory of Constraints, Lean and Six Sigma. The program emphasizes continuous process improvement to the Naval Aviation culture.
- The NAVAIR 4.1 Competency, Systems Engineering, has been actively involved in improving organizational performance starting with Business Process Reengineering (BPR) …

In addition, objectives within AIRSpeed were similar to those established for optimizing the TWD process. Listed below are extracts from a presentation given by Moore (2005) highlighting those objectives:

- "AIRSpeed is all about increasing Productivity to reduce our cost of doing business."
- "AIRSpeed enables the extended enterprise to reduce the cost of doing business using a "System-of-Systems" approach."

The application of process modeling is not just limited to NAVAIR, but has been in use in numerous industries and other DoD services. The USAF has applied lean initiatives tools within their aircraft depots (Christopher 2005). These tools are similar to those applied to the TWD process, such as value stream mapping, lean enterprise self-assessment tool, or PDMCAT[1] that assess the life cycle of the process across the

[1] Developed by Rand Corporation for Project Air Force as a Depot Capacity Assessment Tool.

enterprise and provide understanding of key constraints influencing the process (.Loredo, Pyles, Snyder, 2007). Other industries such as healthcare, manufacturing, aerospace, transportation, and supply chain management employ these tools to reduce the cost of doing business.

2. Building of the Model

The model shown in Figure 13 was started in iGrafx by creating the top-level process first and then adding the sub-processes CAT A through CAT C on Figure 13, after the top-level process was completed. In addition, the model used factors derived from historical data from multiple test programs conducted at NAWCAD Pax River. The factors included the likelihood of scheduling a technical review as well as successfully passing the review. The TWD development start date was set at 7 January 2009.

The author entered the top-level process into iGrafx by selecting ‘Process’ on the File Menu. The author selected process format because it had the ability to represent accurately the TWD process, and is the iGrafx recommended modeling format. Figure 14 is a snapshot illustrating the selection of the model format. The basic process flow was mapped into iGrafx by selecting the appropriate flowchart symbol. The author used standard flowchart symbols in iGrafx decision points, process steps, connectors and termination points, which made the process creation straightforward. Figure 18 shows these symbols.

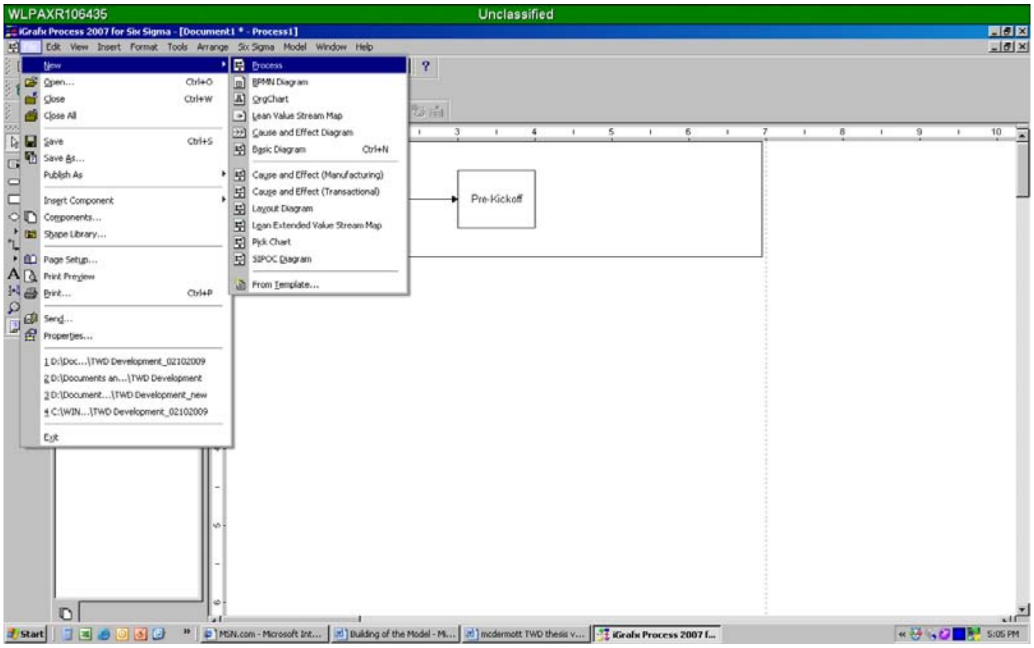

Figure 13. Snapshot of Selecting Process Format

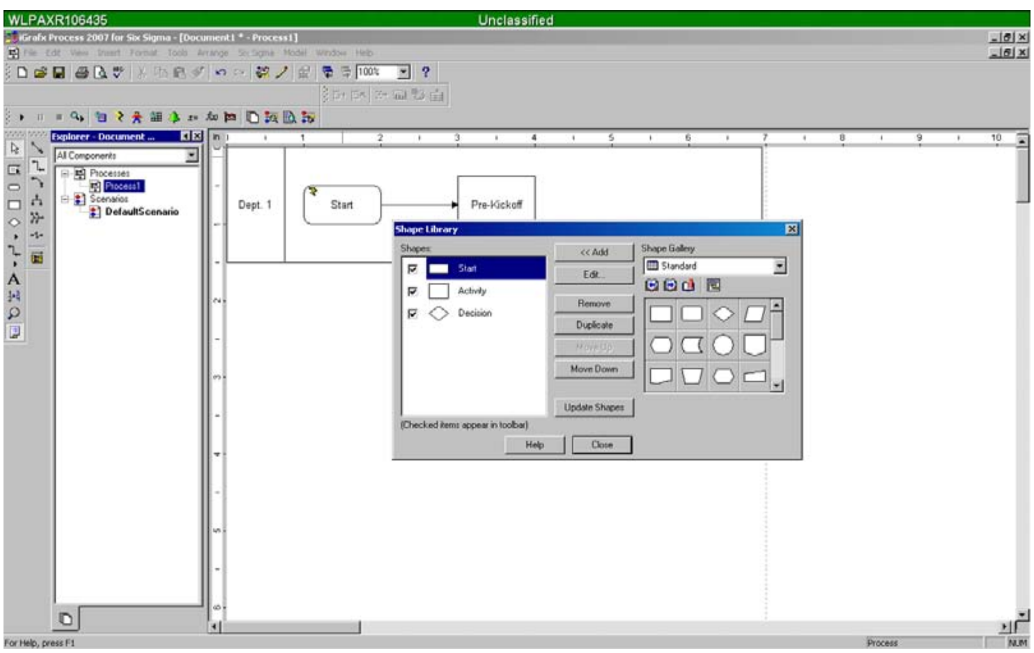

Figure 14. Menu of Flowchart Symbols

Each step in the process had specific properties assigned to control its behavior within the process. The property elements used for each step were input, task, resource, outputs, attributes, and last simulation. The first element, input property established the "queuing rules" for how the data enters and exits the process step. The TWD model queuing rule used was "first in first out," meaning all TWDs' priorities were equal as they enter into the process step.

The next element was resources. This element defined the time required to complete the work associated with the process step. It allowed for a constant time, a distribution of time, or an expression to represent the resource allocation. The TWD model used a constant allocation that was dependent on the resource type and TWD complexity. Each step had its resource pool built to support that process step. The initial allocation for the TWD model was completed in the Requirements Review step. For example, if the TWD required a test conductor and was a category C complexity, the constant value for the test conductor would be 0.6, or 60 percent, of his time assigned to that TWD. If the complexity was a category A TWD, the constant value for the test conductor would be 0.4, or 40 percent, of the test conductor time allocated to the TWD.

1. Category B and C

   60 percent of time per TWD per test conductor

   40 percent of time per TWD per test team member

2. Category A

   40 percent of time per TWD per test conductor

   30 percent of time per TWD per test team member

Multiple process steps such as Requirements Review, TTRB Look Ahead, TTRB, and TTRB Action Resolution had the resource pool created within iGrafx. Listed below are the inputs incorporated into the model as constraints within the resource pool for the different TWD categories. Figure 15 shows a snapshot of the resource pool used for Requirements Review.

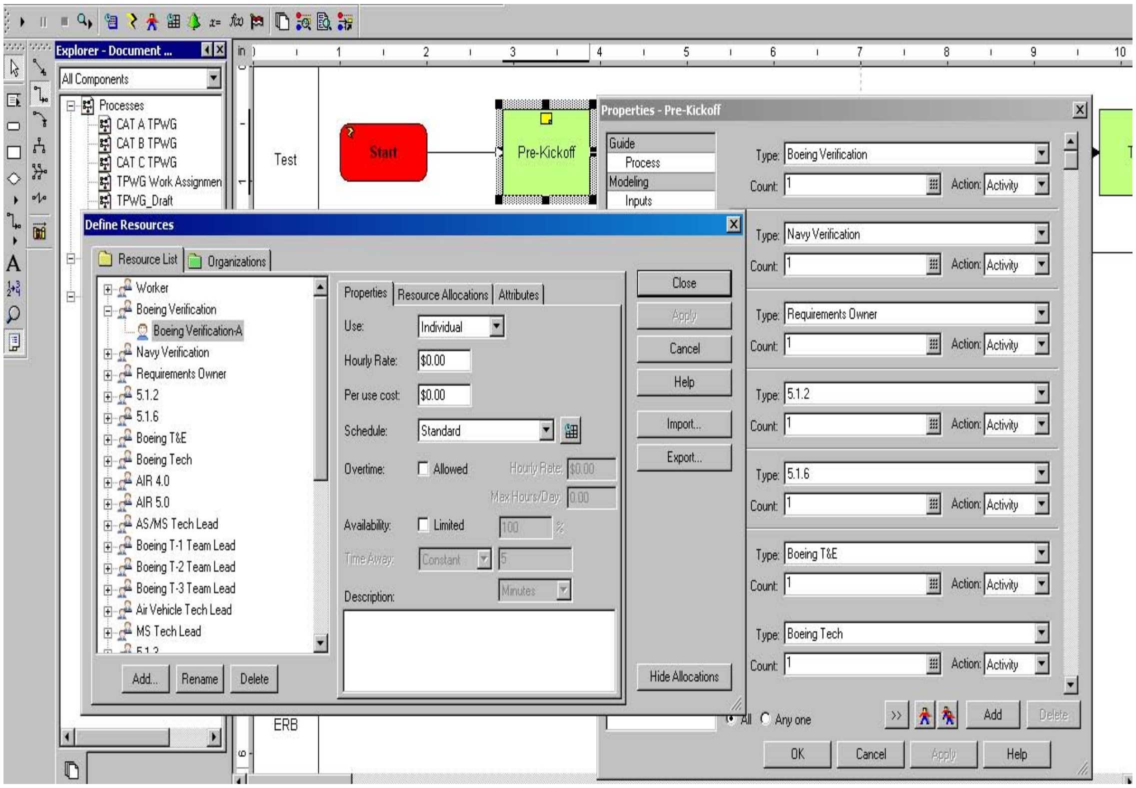

Figure 15. Screen Shot for Requirements Review

The next property element is task. This property element defined how long the process step takes to complete. Options for this element were a constant value, normal distribution, a uniform distribution, or an expression. The TWD model used a normal distribution to represent the following process steps: Requirements Review, TPWG (1st Draft), Prepare for TRA, Prepare for ERB. The distribution range was derived from historical data from prior NAVAIR test programs. The minimum range was one to three weeks and the maximum range was six to fourteen weeks. The remaining steps were constant duration and varied from one to three weeks depending on the process step.

The final property element used in the TWD model was output. This element was used to establish decision criteria within the process step. The TWD model used the decision criteria to represent the likelihood of a TWD entering into a technical review successfully and receiving approval from the review. The model used historical data from prior test programs to establish the probabilities for each review. The likelihood values for a TWD successfully passing each technical review are given below.

1. Technical Review Board–50 percent
2. Technical Readiness Assessment–75 percent
3. Executive Review Board–50 percent

Figure 16 shows an example of the likelihood entries for the Technical Readiness Review.

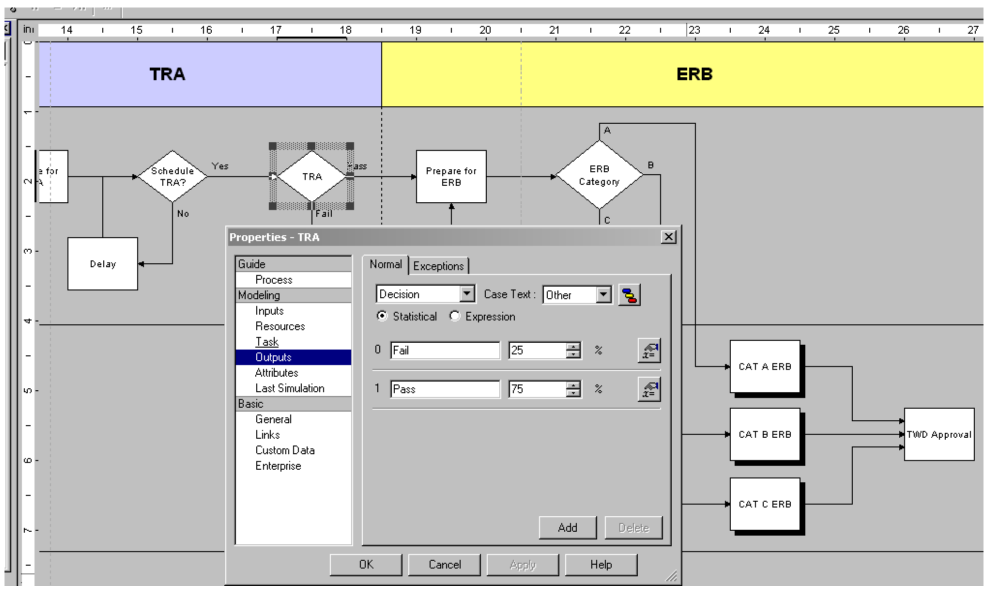

Figure 16. Decision Entries for Output Element for Technical Readiness Review

The next event in the model-build process was the creation and integration of the sub-processes. These sub-processes addressed the approval paths that TWDs of the different categories follow through the ERB process and are shown in Figure 17. The only difference between the sub-process for Category A and Categories B and C was the likelihood of scheduling a review. Figure 18 displays the sub-process for Category A. The factors used for the potential of successfully scheduling the review are as follows:

1. Technical Review Board–85 percent
2. Technical Readiness Assessment–75 percent
3. Executive Review Board
   - Category A–90 percent
   - Categories B/C–50 percent

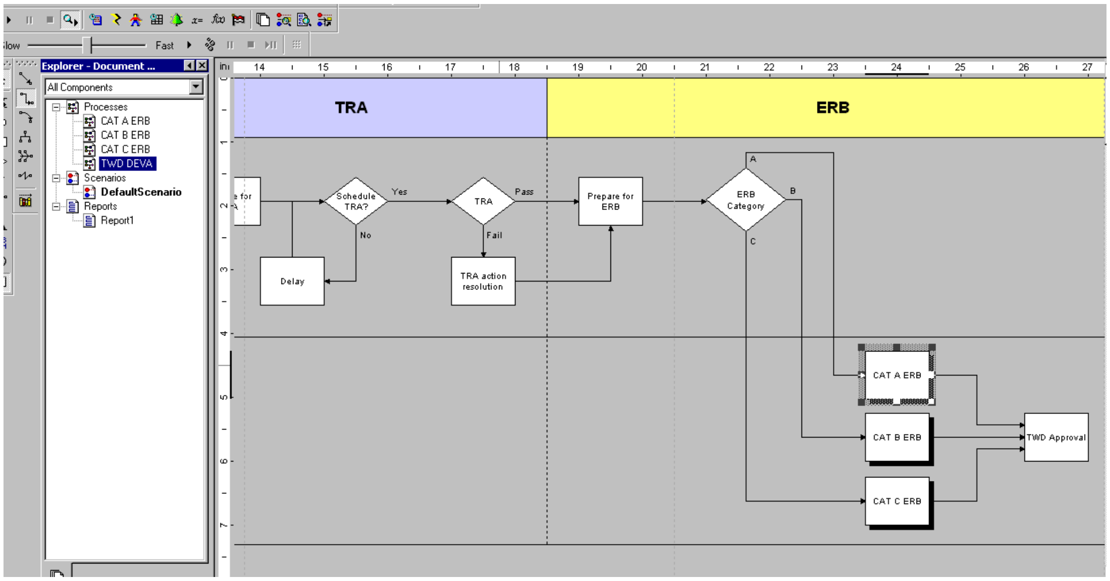

Figure 17. Display of Sub-processes Integration at Executive Review Board

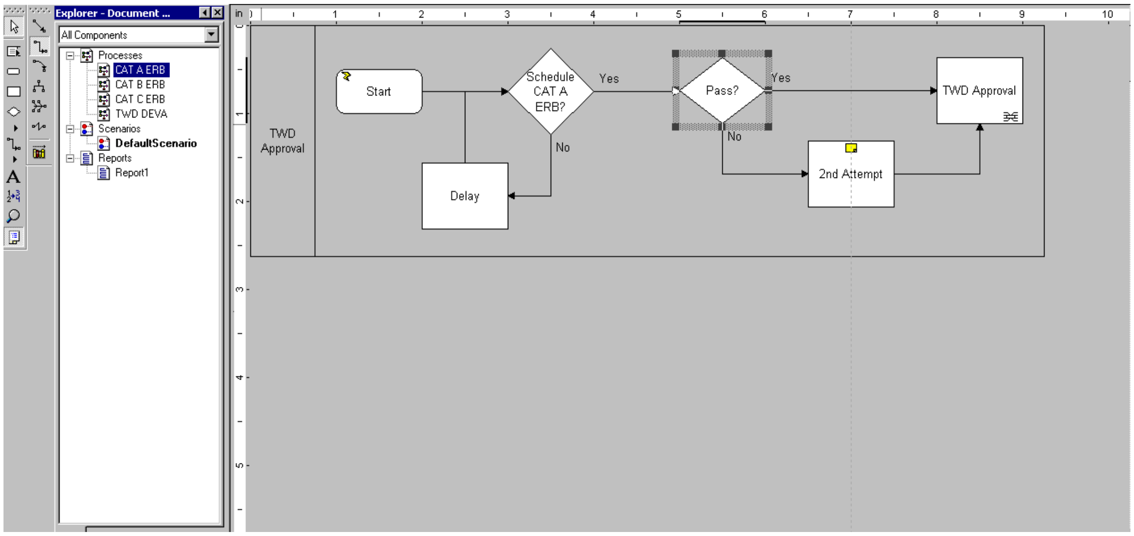

Figure 18. Category A Sub-process

The final step in the TWD model construction prior to running the simulation was the creation of the generator. The generator introduces the transaction to the process. In this model, a transaction is a TWD with its associated attributes. The generator is populated by importing an Excel file that contained all the TWDs and their associated attributes such as complexity, category, required personnel, and expected need date. Two prime factors within the Excel file were the priority and complexity of the TWD. The ITT established priority based on the date the TWD needed to be approved to support the test schedule. The complexity was rated on a 1 to 10 scale. They based the complexity score on multiple factors shown below:

- The complexity score increased as the quantity of design/performance requirements verified by the TWD increased.
- The complexity score increased as the quantity of ground and/or flight-test hours increased.
- The test category (A/B/C) influenced the complexity score. A category C has a higher complexity score than a category A or B. A category B has a higher score than a Category A.

The generator menu allowed for selection of a generator type. The different generator choices were completion, demand, inter-arrival, and timetable. The generator type the TWD model used was a demand generator. This generator type introduced a transaction whenever the named resource (for example, test conductor) was available. Figure 19 depicts the generator menu option selected to import external data. The data were fed into the TWD model as transactions were processed and resources became available.

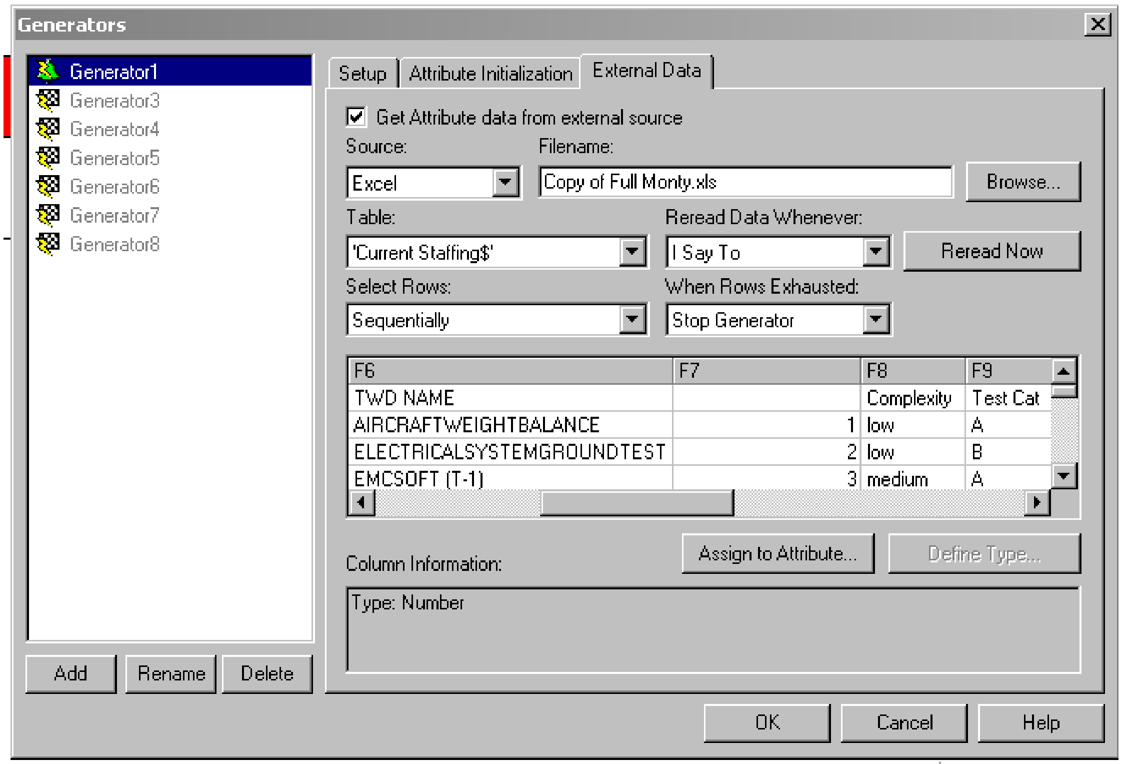

Figure 19. Snapshot of the Menu for the TWD Generator

C. TWD PROCESS SIMULATION

1. Simulation Model Inputs

The initial step of the model is to import the resource table shown in Table 5. This table provides the available workforce capable of supporting the TWD process and establishes the basis for resource variables influencing the TWD process. The table consists of the name of the TWD, its category, key members of the ITT responsible for developing and managing the TWD, competency lower level technical readiness assessments (TRA), and the Executive Review Board (ERB). The key ITT members are test conductor (TC), primary project engineer (PE), primary project officer (PO), operational tester (OT) representative, flight test engineer (FTE), and instrument operation engineer (IOE). The data table also contains the test category of A, B, or C. As previously stated, the test category also reflects the complexity of the test where a category A TWD is the least complex and category C TWD is the most complex. The complexity also determines the number of technical reviews and the time required for each ITT member supporting the TWD process. Under each of the ITT members is further specification of areas of specialization. For example, under TC and radar TWD, the requirement is the individual must be from Boeing (B) and have a mission systems (MS) background. Actual allocated support hours were imported into the model. Figure 20 provides a snapshot of the Government's ITT labor profile. The allocation of labor becomes a constraint within the model.

Table 5. TWD Process Personnel Data

TWD Name	Test Conductor	Project Engineer	Project Officer	Operational Test Representative	Flight Test Engineer	Technical Engineer	Contractor Flight Test Director	Government Flight Test Director	TRA Authority	VX-20 Squadron ERB
AIRCRAFT WEIGHT & BALANCE	B, TC, AS	DT, PE, AS, AEROMECH	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH LEAD	CFTD	GFTD	5.1.6.3	CAT A ERB
FUEL SYSTEM GROUND TEST	B, TC, AS	DT, PE, AS, MECH SYS	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH LEAD	CFTD	GFTD	5.1.6H-MECHSYS	CAT B ERB
ECS GROUND TEST	B, TC, AS	DT, PE, AS, MECH SYS	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH LEAD	CFTD	GFTD	5.1.6.13	CAT A ERB
ELECTRICAL SYSTEM GROUND TEST	B, TC, AS	DT, PE, AS, MECH SYS	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH LEAD	CFTD	GFTD	5.1.6H-MECHSYS	CAT B ERB
EMC SOFT	B, TC, MS	DT, PE, MS, EEE	DT, NFO, PO, MS	OT, NFO, PO, MS	FTE	MS, TECH LEAD	CFTD	GFTD	5.4.4.5	CAT A ERB
HUMAN FACTORS	B, TC, HF	DT, PE, AS, HUMAN FACTORS	DT, NFO, PO, MS	OT, NFO, PO, MS	FTE	MS, TECH LEAD	CFTD	GFTD	5.1.6.3	CAT A ERB
AIRCREW GROUND EGRESS DEMO	B, TC, AS	DT, PE, AS, MECH SYS	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH LEAD	CFTD	GFTD	5.1.6H-MECHSYS	CAT B ERB
EXTERNAL FIELD OF VIEW GROUND DEMONSTRATION	B, TC, AS	DT, PE, AS, GENERIC	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH LEAD	CFTD	GFTD	5.1.6.3	CAT A ERB
FQ FLIGHT TEST - CLEAN	B, TC, AS	DT, PE, AS, FQ	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH LEAD	CFTD	GFTD	5.1.6H-AEROMECH	CAT C ERB
STRUCTURAL LOADS GROUND & FLIGHT TEST - CLEAN	B, TC, AS	DT, PE, AS, LOADS	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH LEAD	CFTD	GFTD	5.1.6H-AEROMECH	CAT C ERB
FLUTTER FLIGHT TEST - CLEAN	B, TC, AS	DT, PE, AS, FLUTTER	DT, PILOT, PO, AS	OT, PILOT	FTE	AS, TECH LEAD	CFTD	GFTD	5.1.6H-AEROMECH	CAT C ERB

SDD TWP REQUIREMENTS									
TEAM	SUB TEAM	Name	RD #	COST CAT	GS Level	LOC	Code	Functional Area	WY
LEAD									
PT	Lead	Mac Brown	223702, 223699, 223695	GL	14	PAX	5.1E	Product Test Team Lead	0.90
PT	Lead	Tony Schmidt (On-Site)	223625, 223624, 223622	GL	14	PAX	5.1E	Product Test Team Deputy	0.90
PT	Lead	Kelly VanRyswick (On-Site)	98817	CL		PAX	CSS-ManTech	System Eng/T&E Analyst	0.50
PT	Lead	TBD (VX-1) (Off-Site)	Exempt	CL	OS	PAX	CSS-RBC	Operational Test Analyst	1.00
PT	Lead	Tanya Bassett (On-Site)	98814	CL		PAX	CSS-RBC/Wyle	AV Verification Matrix	1.00
PT	Lead	Mark Sweet (CDR)	98811	GL	15	PAX	5.1G	Chief Test Engineer (VX-20)	0.05
PT	Lead	Steve Gateau (On-Site)	98816	CL		PAX	CSS-RBC/Precise	Information Technology	1.00
PT	Lead	Material		MAT		PAX		Material	
PT	Lead	Travel		TVL		PAX	Travel		
ITT Lead (GFTD)									
PT	ITT	TBD (On-Site) (ITT)		CL		PAX	CSS	GFTD Admin Support	0.00
PT	Lead	Amy Mattingly (On-Site)	Exempt	CL		PAX	CSS - RBC	ITT/T&E Analyst	1.00
PT	ITT	TBD (On-Site) (ITT)	256398	CL		PAX	CSS	ITT Scheduler	0.25
PT	ITT	TBD (On-Site) (ITT)		CL		PAX	CSS	ITT Scheduler	0.00
PT	ITT	TBD (On-Site) (ITT)		CL		PAX	CSS	Budget Support Analyst	0.00
PT	ITT	TBD (On-Site) (ITT)		CL		PAX	CSS	IT Coordinator	0.00
PT	Lead	Troy Knott (On-Site)	Exempt	CL		PAX	CSS-RBC	Security (Physical)	0.00
PT	ITT	Pat Leard (On-Site) (ITT)	256396	GL	14	PAX	5.1.3	Test and Data Lead	0.80
PT	ITT	TBD (On-Site) (ITT)	256397	GL	13	PAX	5.1.3	FCRA	0.10
PT	ITT	TBD (On-Site) (ITT)		GL	13	PAX		GFR	0.00
PT	ITT	TBD (On-Site) (ITT)		GL	13	PAX		GGFR	0.00
PT	ITT	TBD (On-Site) (ITT)		GL	12	PAX		Photographer	0.00
PT	ITT	TBD (On-Site) (ITT)		GL	13	PAX		ALSS-T2	0.00
PT	ITT	TBD (On-Site) (ITT)		GL	13	PAX		A/C Config Mgmt	0.00
PT	Lead	Material		MAT		PAX		Material	0.00
PT	Lead	Travel		TVL		PAX	Travel		0.00
ITT MILITARY									
PT	ITT	James Reining (CDR)	358915, 358911, 358909	ML		PAX	5.1.3	GFTD	1.00
PT	ITT	John Verniest (CDR)		ML		PAX	VX-1	OTD	1.00
PT	ITT	Kevin Doney (CDR)	359535	ML		PAX	5.1.6.3		1.00
PT	ITT	Saglimbene (LT)	359535	ML		PAX	VX-1		1.00
PT	ITT	Olson)LT)	359535	ML		PAX	VX-1		1.00
PT	ITT	Calloway (LT)	359534	ML		PAX	5.1.3		1.00
PT	ITT	Lewis (LT)	359534	ML		PAX	5.1.3		1.00
PT	ITT	Drake (LT)	359534	ML		PAX	5.1.3		1.00
PT	ITT	Class 136 Pilot	359533	ML		PAX	5.1.3		1.00
PT	ITT	Class 136 Pilot	359533	ML		PAX	5.1.3		1.00
PT	ITT	Johnson TJ (CDR)	359601	ML		PAX	5.1.3		1.00
PT	ITT	Lazenka (LT)	359601	ML		PAX	5.1.3		1.00
PT	ITT	Webb (LT)	359600	ML		PAX	5.1.3		1.00
PT	ITT	Walsh (LT)	359600	ML		PAX	5.1.3		1.00
PT	ITT	NFO VX-1	359599	ML		PAX	VX-1		1.00
PT	ITT	AW 1	359540	ML		PAX	5.1.3		1.00
PT	ITT	AW 2	359540	ML		PAX	5.1.3		1.00
PT	ITT	AW 3	359540	ML		PAX	5.1.3		1.00
PT	ITT	AW 4	359540	ML		PAX	5.1.3		1.00
PT	ITT	AW 5	359540	ML		PAX	5.1.3		1.00
PT	ITT	AW 6	359540	ML		PAX	5.1.3		1.00
PT	ITT	AW 1	359540	ML		PAX	5.1.3		1.00
PT	ITT	AW 2	359540	ML		PAX	5.1.3		1.00
AIR VEHICLE									
PT	AV	Jason Allred (AV)	98810, 98809, 98808	GL	14	PAX	5.1.6.3	Air Vehicle T&E Lead	0.80
PT	AV	William Lang (AV)	98807, 98806, 98805	GL	13	PAX	5.1.6.3	Aeromechanics (Lead)	0.90
PT	AV	TBD (AV)	98807, 98806, 98806	GL	14	PAX	5.1.6.3	Aeromechanics Branch Head - USN	0.00
PT	AV	Jason Brys (AV)	98807, 98806, 98807	GL	13	PAX	5.1.6.3	Aeromechanics (Loads)	0.70

Figure 20. Government ITT Labor Profile

2. Simulation Approach

The approach was to run the model to obtain predictions of performance while varying the resource levels and determining the amount of time required to complete all the TWDs. The author modeled three alternatives (A, B, and C) and a baseline and the results were compared. The baseline case was the current work force level. The current workforce maintains existing manpower resource levels to draft and process TWDs while they also conducted flight-testing. This means the members spend 50 percent of their time working on TWDs and 50 percent of their time conducting flight-testing. This represented the lower bound of resources and led to the upper bound of time. Alternative A maintained current staffing levels to process the TWDs and augmented the ITT to conduct flight-testing. Alternative B augmented the ITT staff in known critical skill sets, such as test conductors and project test engineers, beyond the 100 percent staffing used in Alternative A to work on TWDs and conduct testing. Several iterations were used before a final staffing configuration was found for Alternative B as described in the next paragraph. Alternative C was constructed with unlimited resources in order to determine the earliest time TWDs could be completed and to identify the workforce needed to accomplish the effort at that rate. This represented the upper bound of resource and led to the lowest bound of time. The author identified Alternative C as the "ideal solution," but it carried a larger cost than the other concepts.

Early simulation runs of the model supported sensitivity analyses to determine if there were any critical resources. The author performed the analyses by plotting task completion time against the number of workers. Examples of the sensitivity assessment for Boeing test conductors, USN developmental test pilots, and USN mission systems project engineers are shown in Figures 21 through 23. The assessment identified three key resource elements that influenced TWD completion. The knee in the curve on each graph was used to establish the optimal resource levels. The knees occur at the point where adding resources ceases to reduce the processing time significantly. For example, the knee in Figure 21 for aircraft systems test conductors occurs at about the point where there are 28 test conductors. Adding more test conductors (beyond 28) does not further reduce the processing time. Similarly, the knees in the curve for the DT Pilots and PE Mission Systems were at 11 and 12 workers respectively. The final Alternative B configuration was based on this staffing level information.

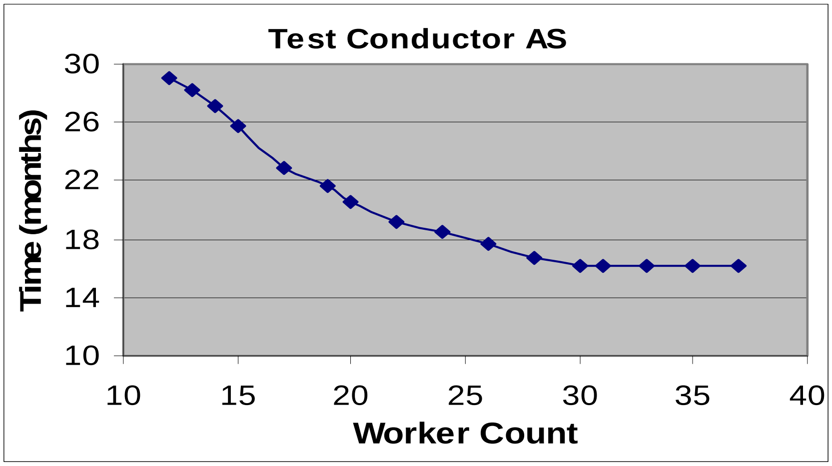

Figure 21. Test Conductors Sensitivity Analysis

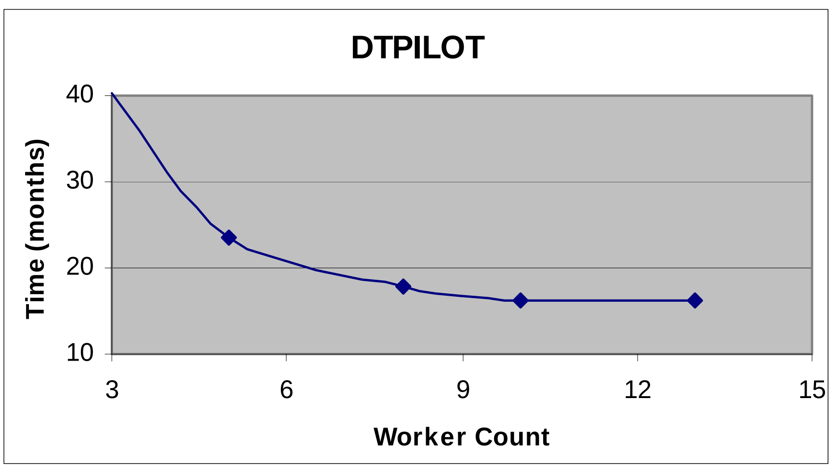

Figure 22. Developmental Test Pilots Sensitivity Analysis

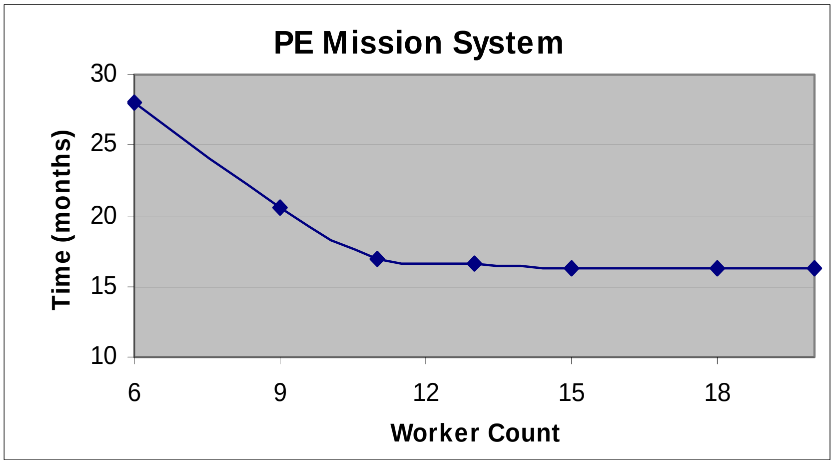

Figure 23. Mission Systems Project Engineer Sensitivity Analysis

3. Simulation Validation

Figure 24 presents the early simulation results used to assess the model's accuracy. The graph shows the model's prediction compared against actual status for the first 17 TWDs. These are required to conduct testing on the first P-8 test aircraft (T-1). The data shows the number of TWDs completing the four phases of the TWD process. It compares the number of TWDs the model projected with the actual numbers completed in the phase. The close agreement of the data validates the model. The results provided enough confidence that the author updated the model to run all 72 TWDs. These TWDs covered ground and flight-testing for the three test aircraft, T-1, T-2, and T-3. Table 6 shows the list of the 72 TWDs for imported into the model.

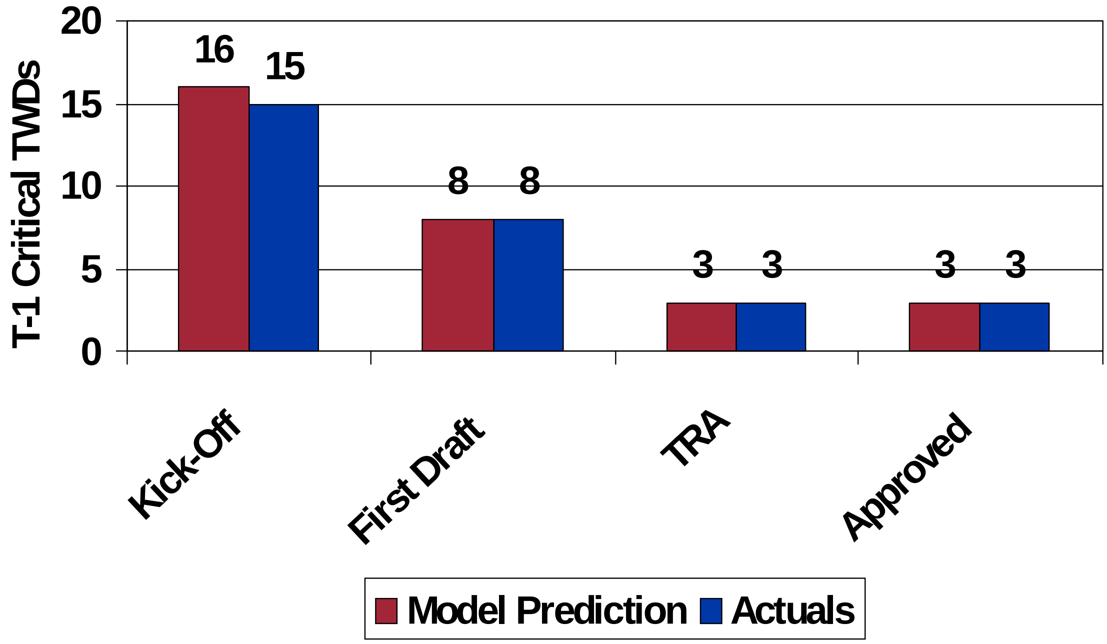

Figure 24. Early Simulation Results

Table 6. List of the 72 TWDS

TWD NAME	Orde	Complexity	Test	TYP	TWD NAME	Orde	Complexit	Test	TYP
AIRCRAFTWEIGHTBALANCE	1	low	A	AS	FLUTTERFLIGHTTESTSTORES	37	medium	C	AS
ELECTRICALSYSTEMGROUNDTEST	2	low	B	AS	PROPULSIONSYSTEMTHERMALPERFORMANCEF	38	medium	C	AS
FULLSCALEAIRFRAMELOADSCALIBRATION	3	medium	A	AS	AERIALREFUELINGFLIGHTTESTTWDF03F002	39	high	C	AS
EMCSOFT	4	medium	A	MS	IFFIFLIGHT	40	medium	A	MS
HUMANFACTORS	5	medium	A	MS	ESMGROUNDFLIGHT	41	high	A	MS
GROUNDVIBRATIONTESTCLEANWING	6	medium	A	AS	NAVGROUNDFLIGHT	42	medium	A	MS
STRUCTURALMODEINTERACTIONCLEANTWD	7	medium	A	AS	ECSFLIGHTTEST	43	medium	A	AS
AIRCREWGROUNDEGRESSDEMO	8	low	B	AS	STORESFITCOMPATIBILITYGROUNDTEST	44	medium	A	AS
FQFLIGHTTESTCLEAN	9	high	C	AS	STRUCTURALLOADSFLIGHTTESTSTORES	45	medium	C	AS
STRUCTURALLOADSGROUNDFLIGHTTESTCLEAN	10	medium	C	AS	INTEGRATEDMISSIONSYSTEMOPERATIONSGROU	46	high	A	MS
FLUTTERFLIGHTTESTCLEAN	11	medium	C	AS	AIRBORNEEMERGENCYEGRESSDEMONSTRATIOI	47	medium	C	AS
TAXIPRELIMINARYFLIGHTEVAL	12	medium	C	AS	NOISEVIBEFLIGHTTESTSTORES	48	medium	C	AS
PERFORMANCEFLIGHTTESTCLEAN	13	medium	C	AS	PROTECTIONFROMUNAUTHORIZEDENTRYDEMOI	49	low	A	AS
TRAILINGCONESECFLIGHTTEST	14	medium	C	AS	CREWINTERIORNOISEANDAUDIBILITYFLIGHTTEST	50	low	A	AS
FUELSYSTEMFLIGHTTEST	15	medium	B	AS	MAINTAINABILITYDEMONSTRATION	51	low	A	AS
ELECTRICALSYSTEMFLIGHTTEST	16	medium	B	AS	GROUNDANDFLIGHTTRAININGSIMULATORTESTIN	52	medium	A	AS
AERODYNAMICCONFORMITYGROUNDTEST	17	low	A	AS	EOIRFLIGHT	53	medium	A	MS
ECSGROUNDTEST	18	low	A	AS	COMMVOICEGROUNDFLIGHT	54	medium	A	MS
HEALTHMANAGEMENTSYSTEMFLIGHTTEST	19	medium	A	AS	EMCSOFT	55	low	A	MS
CREWALERTING	20	low	A	MS	CLIMATICCHAMBERGROUNDTEST	56	medium	A	AS
ENHANCEDDIGITALFLIGHTCONTROLSEDFCS	21	medium	C	AS	TEMPEST	57	low	A	MS
FLIGHTMANAGEMENTCOMPUTINGSYSTEMFMCS	22	medium	A	AS	STORESSTRUCTURALMODEINTERACTIONTEST	58	medium	A	AS
SERVICELIFETRACKINGTESTANDDEMONSTRATIC	23	medium	A	AS	FREEPLAYANDRIGIDITYTEST	59	medium	A	AS
HEALTHMANAGEMENTSYSTEMGROUNDTESTAN	24	medium	A	AS	STORESGROUNDVIBRATIONTEST	60	medium	A	AS
DYNAMICSTORESRELEASE	25	medium	C	AS	ACOUSTICSGROUNDFLIGHT	61	high	A	MS
GROUNDHANDLINGTEST	26	medium	B	AS	WEAPONSINTEGRATIONSMSGRD	62	high	B	MS
FQFLIGHTTESTSTORES	27	high	C	AS	WEAPONSFLTANDDELIVERYACCURACY	63	medium	C	MS
RADARFLIGHT	28	medium	A	MS	COMMDATALINKSGROUNDFLIGHT	64	medium	A	MS
EWSPFLIGHT	29	medium	B	MS	EEE	65	medium	A	MS
PROPULSIONPOWERTHERMALGROUND	30	medium	B	AS	HUMANFACTORSFULLMISSION	66	medium	B	MS
NOISEVIBEFLIGHTTESTCLEAN	31	medium	C	AS	WEAPONSSEPARATION	67	high	C	AS
AIRCREWGROUNDEGRESSDEMO	32	low	B	AS	ICINGSYSTEMTEST	68	medium	C	AS
AERIALREFUELINGSIMULATIONGROUNDTEST	33	medium	B	AS	WEAPONSDELIVERYACCURACY	69	medium	C	MS
BUFFET	34	high	C	AS	AIRCRAFTRESPONSEANDTURNAROUNDTIMEDEI	70	low	A	AS
OBIGGSGROUNDTEST	35	low	B	AS	TAXIPRELIMINARYFLIGHTEVALDEMONSTRATION	71	medium	C	AS
OBIGSSFLIGHTTEST	36	medium	B	AS	PERFORMANCEFLIGHTTESTSTORES	72	medium	C	AS

4. Improved TWD Model

Since May 2009, monthly simulation runs have been generated to track the accuracy of the model. Figure 25 is a plot of the T-1 TWD status for a simulation run performed in late July 2009. The data reveals that the model continues to track well for each phase of the TWD process, confirming the value of the tool. A small number of TWDS were initiated back in October 2008. These TWDs continued through the process and the first one received approval in January 2009. The model's start date was January 2009. This difference of initiation date accounts for the early differences on approved TWDs.

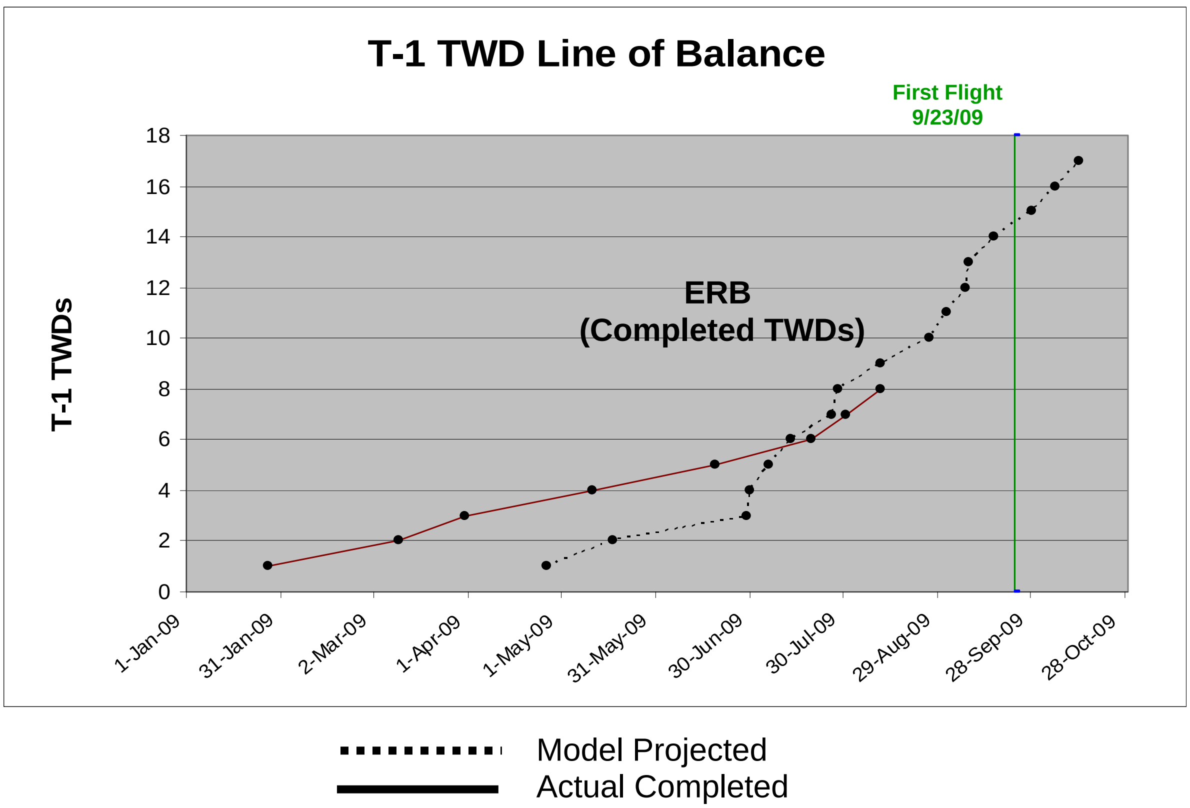

Figure 25. Model Predictions vs. Actual T-1 TWD Data

D. CHAPTER SUMMARY

The chapter explained the TWD process improvements derived from a functional analysis prior to computer modeling. It provided an explanation of the four-phase process concept and expected benefits of moving to new process.

This chapter outlined the search for commercially available process modeling software meeting specific requirements associated with cost, software availability, and ease of use. Results from the research identified a preferred software suite produced by Corel know as iGrafx.

This chapter introduced the objective of the TWD model and reviewed other research applications in the projects of Lean Enterprise and NAVAIR AIRSpeed. There was a strong correlation with NAVAIR and USAF depot maintenance capacity models. Their focus was on throughput of hardware, while the TWD model product was the creation of documentation. Earlier projects were also interested in understanding the resource requirements to achieve their objectives. These were also products of the TWD model of interest to P-8A Program Management.

This chapter described the building of the TWD model. It explained the various entries as the TWD model was assembled. It described the creation of the software model implementation of the four-phase approach. It identified data files imported into the model. Finally, define the factors modeled and the basis of those factors.

The chapter discussed how sensitivity models for labor categories were developed and interpreted to determine critical resource categories and the resource requirements needed to execute efficiently the TWD process.

Finally, the chapter presented results from simulation runs conducted on the current workforce and three alternatives. It compared the alternatives back to the baseline to determine the impact of the various resource levels on the TWD process. Early results were validated with actual TWD production rate by the ITT. Results from the simulations showed how to allocate the resources to balance cost and schedule while meeting the test program's test schedule.

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V. ANALYSIS OF RESULTS

A. INTRODUCTION

The author conducted several simulation runs to identify the necessary resources required to move the TWDs through the process. Figure 26 is the plot of those simulation runs. The plot represents the projections of the number of TWDs completed for a given resource level and the date when all TWDs are completed. The graph shows the baseline plan established in April 2008, and the re-baseline conducted in December 2008. It also displays the model's prediction based on a new start date, January 2009 ITT staffing levels, and the three alternatives. The plot has three vertical lines labeled T-1, T-2, and T-3. T-1, T-2, T-3 are designations for aircraft provided to support the flight test program. The T-1, T-2, and T-3 on the plot represents the dates when the T-1, T-2, and T-3 aircraft commence flight-test and establish the target date for TWDs to be completed to support the testing. The chart also has the estimated TWD execution rate. Approximately 4.3 TWDs completed or executed is the average monthly rate. Six in a given month is the estimated maximum numbers of TWDs executed. The minimum number of TWDs in a given month is one. Some TWDs like flutter or flying qualities will be in execution for several months before being completed.

The plots of the baseline and rebaseline depict a very aggressive schedule and predicted all the TWDs would be completed to support the flight test program. However, neither plan was staffed for this type of execution. The model predicts that the January 2009 resource level and the three alternatives support the date for T-1 to begin flight-testing. However, the plots begin to diverge from each other shortly after meeting the initial need dates. Alternative B was identified as the "optimal" approach that completed TWDs by their required test date while balancing resources. This so-called optimal approach was determined as the alternative for which the cumulative number of TWDs delivered equaled or exceeded the cumulative number of TWDs that could be completed by test aircraft in the actual flight test program.

The most optimistic flight test program would immediately start consuming TWDs on the test aircraft delivery dates shown on Figure 26 at the lines labeled T-1, T-2, and T-3. Alternative B will meet the required TWD completion dates provided test aircraft do not exceed an average test completion rate of about 4.3 TWDs per month per aircraft.

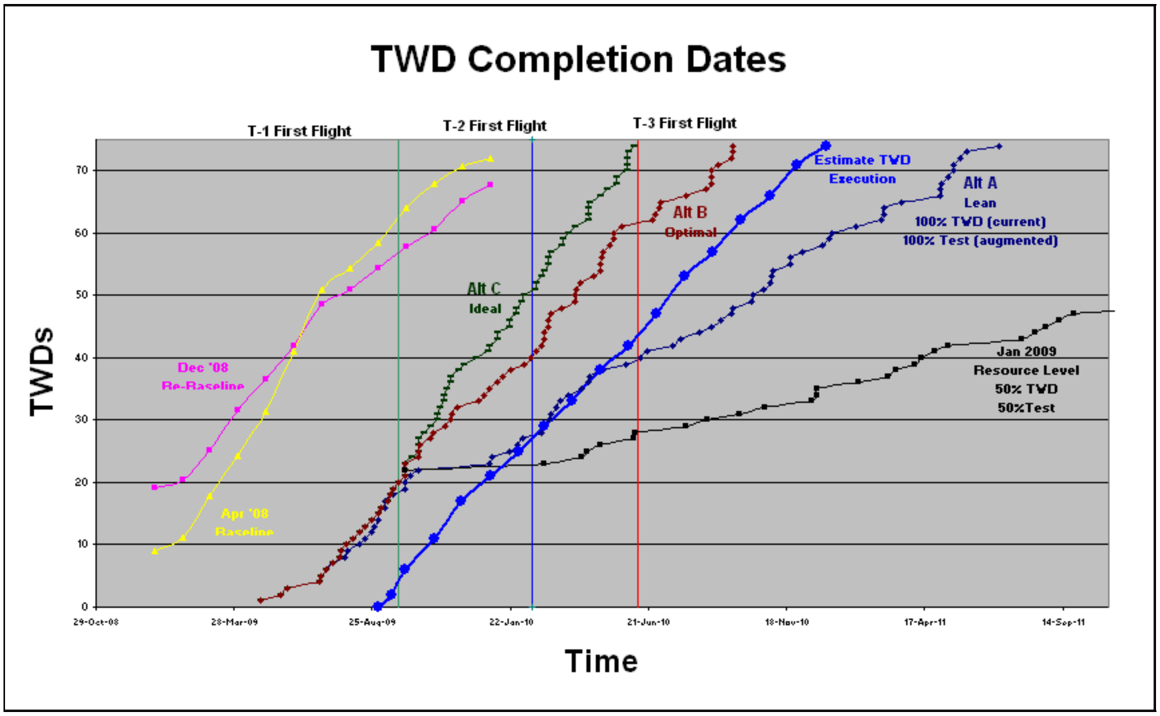

Figure 26. Simulation Results for Processing TWDs at Various Resource Levels

Tables 7 and 8 provide a summary of the results for required resources. Table 7 presents a comparison of the resource levels of the three concepts of alternative and the baseline. There is a significant difference between the baseline and Alternative C. Table 8 compares the Alternative B optimal workforce with the baseline. It also provides the percent of increase to resource to that level. The study shows the largest increase need is for test conductors. This finding is consistent with the situation in other test programs within NAVAIR. The primary reason for this large increase is that a test conductor is usually dedicated to a single TWD and oversees it from creation to final approval.

Table 7. Resource Results of the Alternative Concepts

Test Personnel	Baseline (31 Jan 09 Resources)	Alt A	Alt B	Alt C
TC AIR	6	12	22	28
DT Pilot	4	8	8	11
PE Air	11	22	22	34
OT Pilot	5	10	15	15
TC MS	4	8	14	16
DT NFO	3	5	5	8
PE MS	5	9	11	12
OT NFO	5	10	9	10

Table 8. Resource Requirement for the Improved TWD Process

Test Personnel	Baseline (31 Jan 09 Staffing)	Alt B (Optimal Staffing)	%Change
TC AIR	6	22	266.67%
DT Pilot	4	8	100.00%
PE Air	11	22	100.00%
OT Pilot	5	15	200.00%
TC MS	4	14	250.00%
DT NFO	3	5	66.67%
PE MS	5	11	120.00%
OT NFO	5	9	80.00%

B. CHAPTER SUMMARY

This chapter discussed the results of the TWD model. It presented the model's baseline predictions and the three alternatives. It examined alternatives that ranged from a baseline condition that was limited by the existing January 2009 ITT resource level (the lower bound) to an upper bound that assumed unconstrained resources. The upper bound conditions were chosen to determine earliest time the TWDs could be completed. Other options whose conditions were in between those boundary conditions were also analyzed until it was possible to identify an "optimal" resource level to support the test program.

An alternative (Alternative B) was identified that delivered TWDs at rate such that the flight-test schedule was not delayed. The selected alternative required the ITT resource levels to increase by approximately 150 percent over the baseline. This rate set staffing levels at the appropriate levels to meet the schedule, thus Alternative B is the optimal solution among the alternatives considered.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The ability of the test working description (TWD) model to predict effects of process changes has confirmed there is an opportunity to work an "optimal" solution of balancing resources (cost, personnel), schedule and technical requirements (TWDs in this case). The P-8A test program was having trouble writing test working descriptions (test plans) and getting them approved soon enough to meet the flight test schedule. This research identified process improvements through computer modeling to predict TWD completion dates for various resource levels and minor process changes to improve TWD quality. The study results in the following conclusions:

- The P-8A TWD process can be improved to increase its efficiency even without adding resources. There was an improvement in TWD quality. This quality improvement will reduce the time a TWD remains in the first phase (TPWG).
- Modeling the TWD process to provide accurate and reliable results have been demonstrated. The model's monthly forecasts continue to show strong correlation to actual completion data. The ITT continues to use the model, and results have been presented at program reviews.
- The model helped identify an optimal resource level that, if implemented, would support the P-8A test schedule. Results from the model showed the resource level needed to meet the test dates. The P-8A program has reviewed results from the model and has been allocating resources to the ITT according to Alternative B.
- There is a strong interdependence between work force levels and process execution rates. The model results show the relationship between TWD production rates and the size of the work force. The model also showed there is a maximum throughput and increasing the work force beyond that needed to deliver this maximum throughput has diminishing returns.

B. RECOMMENDATIONS

Results from the TWD model of the "optimized" TWD process have been validated based on comparison of actual TWD data with the baseline alternative analyzed. This study recommends that the improved TWD process be implemented within NAVAIR. In addition, NAVAIR should use the TWD computer process model as a tool to assess resource requirements. Based on application of the model, Alternative B is recommended as the optimal resourcing to complete the 72 TWDs needed for P-8A test program. These results recommend Alternative B for continued implementation within the P-8A program in order to achieve delivery of TWDs in time to support the flight test schedule.

The optimized TWD process reduced a notional five-phase process and leaned it out to a four-phase approach as shown in Figure 17 on page 66. The four-phase approach consists of: 1) requirements review, 2) first draft, 3) technical readiness assessment (TRA), and 4) executive review board (ERB). The notional five-phase process had an additional draft and review between phases 2 and 3 of the improved four-phase process. Early coordination in phase 1, requirements review, allows for this phase reduction. The team discovered that clear definitions of test expectations, roles and responsibilities, required dates, and interdependencies to other testing improved the quality of the initial draft of the TWD.

C. APPLICATION TO OTHER NAVAIR TEST PROGRAMS

The TWD model has flexibility to be adapted to any test program within NAVAIR. The E-2D program is still in its test phase and its participants are actively writing TWDS. The E-2D program could benefit from the model's ability to conduct 'what-if' drills to understand team resourcing. Training in use of the model has begun along with assisting in shaping inputs required for the model.

The NAVAIR Atlantic Test Ranges program has also expressed interest in adapting this model to help schedule range time and identify the resources required to support the scheduling. The Test Range has taken possession of a copy of the model for further assessment.

D. APPLICATION TO OTHER P-8A SYSTEMS ENGINEERING PROCESSES

Two other systems engineering processes used within the P-8A program are the risk management and the engineering change process. The NAVAIR AIRSpeed program is analyzing both of these processes but from a global NAVAIR perspective. Lessons learned on improving the TWD process are being shared with the program. Applying the TWD model to these two processes may be possible. Both programs share the desire to have the optimal resources applied to provide a quality product at the appointed time. Similar to the E-2D and Atlantic Test Ranges adapting the model for their use, the risk and engineering change processes will require an understanding of inputs and assumptions for the model. Specific sub-processes will require modifications but the core model will remain. Adapting the model for their use awaits the results of the AIRSpeed project. That effort is recommended for future research.

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